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Short Communication

How realistic is a racehorse simulator?

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Key words: Racehorse, Simulator, Kinematics.

Abstract

Race jockey training is demanding and technical. Increased horse care costs and demands on time have led to greater availability and use of racehorse simulators during training. Little is known about the accuracy of the simulated movement and therefore how effective they are for developing the desired technique. We quantified and compared sacral rotation and displacement vectors for a racehorse simulator and a real galloping horse. A single inertial measurement unit was placed on the sacrum of six horses (horse) during a training gallop along an all-weather seven furlong gallop and on the highest speed setting 'four' on the simulator. Displacements were calculated in all three axes before being cut into cycles and analysed along with roll and pitch. Displacement and rotation amplitudes were extracted and compared for the horse and simulator. Horse sacral movement parameters were more varied than those recorded on the simulator. The real horse exhibited greater dorso-ventral, medio-lateral and roll amplitude but smaller cranio-caudal displacement amplitude and no difference in pitch amplitude. Displacement trajectory of the simulator when viewed laterally from the left side, was anticlockwise, the opposite direction to that of the real horse leaving the regular use of a simulator during jockey training under question. Use of the racehorse simulator is beneficial to develop specific fitness and to enable physical manipulation into the optimal position. Care must be taken to avoid any detrimental effects of training with the opposite movement trajectory to that experienced during a race. The programming of the simulators may benefit from adaptations to maximise their benefits.

Introduction

Jockeys are a fundamental part of the £3.45 billion British racing industry (Deloitte, 2013). Riding a racehorse requires balance, coordination, flexibility and fitness, which can be trained but take time to develop. Simulators are increasingly used as training aids for skills from flying aircraft to performing surgery (Aggarwal et al., 2010; Kneebone, 2009; Royal Aeronautical Society). The unpredictable nature of horses combined with the energetically costly and visually unstable 'martini glass' position adopted by modern racing jockeys (De Cocq et al., 2013; Pfau et al, 2009) has led to the common use of racehorse simulators to facilitate jockey training. Simulators support objective assessment of a rider's position (Longhurst et al., 2013), allow physical correction and can improve confidence or aid rehabilitation.

The first horse simulators were developed in 1980 and interactive simulators were introduced in 2007 (Racewood Equestrian Simulators). Anecdotally, the movement of a simulator differs from that of a real horse, but no studies have quantified this difference or considered the effect on jockey position. Greater physical effort has been reported when riding a real horse compared to a simulator, however in many cases the novelty of riding a simulator has been held responsible for higher stress levels, suggesting movements are indeed different (Ille et al., 2015).

Despite the inherent differences, many benefits of simulator training of inexperienced jockeys have been reported. These include economical intensive training sessions, reduced risk of injury to the horse or rider falls and greater scope to physically correct technique while improving muscle and movement-specific fitness (Bailey et al., 1997; Hitchens et al., 2012; Kang.et al., 2010). On the other hand, if the differences between a simulator and a real horse are substantial, extensive simulator use may be contraindicated despite safety and practical benefits.

In contrast to walk and trot, gallop is an asymmetrical gait, with asymmetrical movements throughout the stride cycle influencing the interaction between horse and rider (Greve and Dyson, 2013; Robilliard et al., 2007). Such asymmetrical movement can be difficult to simulate and is currently not programmed into racehorse simulators. The implications of the absence of movement asymmetry on the training of jockeys are unknown.

Aim: Quantify and compare rotation and displacement vectors for a racehorse simulator and a real galloping horse.

Objectives: Quantify displacement of the horse and simulator in three axes.

Record the roll and pitch of the sacrum in the horse and simulator throughout a stride.

Objectively compare the difference in parameters recorded from the horse and simulator.

Hypothesis: Kinematics of a racehorse simulator differ significantly from those of real horses.

Materials and Methods

Data collection:

Twelve jockeys were assigned a category based on their experience (Table 1), 1 Elite, 8 Experienced and 3 Intermediate. All jockeys completed a consent form which had undergone review by the Royal Veterinary College's Ethics Committee.

Simulator:

An MK9[1] racehorse simulator set at the highest speed level was used for all simulator testing. An MTw[2] inertial measurement unit (IMU), containing three axis 16g accelerometers, 1200 deg/s gyroscopes and 1.5 Gauss magnetometers, was attached to the sacrum area of the simulator.

Inertial data were collected with an update rate of 30Hz. Data were collected from twelve jockeys (six were also recorded on a real horse) using a set protocol with three 30 second trials in the normal riding position.

Real Horse:

Data were collected from eight jockeys using six Thoroughbred racehorses from the British Racing School. Two ran twice with different jockeys on different days. The MTw[2] IMU was attached to the sacrum of the horse.

Inertial data were collected with an update rate of 30Hz. Horses galloped the length of an all-weather seven furlong (0.88 mile) track routinely used at the British Racing School.

Data processing:

Acceleration data were calibrated and exported using commercial software (Xsens 'MT manager'). Data were filtered (Butterworth 4^{th} order 0.5Hz high pass) to remove drift. Accelerations in 3 axes were integrated to velocity and again to displacement using numerical integration in custom written Matlab[3] scripts. Positive displacements are dorsal, cranial and left with negative being ventral, caudal and right for the three axes. Displacement data were segmented using minima in dorso-ventral sacrum displacement to represent mid-stance of the cycle.

Cycles were interpolated allowing trials to be combined for analysis. Frame numbers for the start and stop of each cycle were saved and used to extract corresponding filtered roll and pitch data.

Data analysis:

Mean and standard deviation values for each horse-jockey combination were analysed using a linear mixed model in SPSS[4] with condition (simulator or horse) and experience level as fixed factors and jockey as a random factor. The cut off for significance was $P \leq 0.05$.

Results

Cycle displacement magnitude, shape and phase of the sacrum differed between the movement of the simulator and that of real horses in all three axes. Shape and phasing of dorso-ventral displacement were similar but the real horses exhibited greater (P=0.014) dorso-ventral displacement within a stride (figures 1, 3 and 5; Table 2) and variation (P=0.004) between strides than the simulator (figures 1 and 5; Table 2).

A fundamental difference exists between the simulator and a real horse in the magnitude and phasing of cranio-caudal displacement within a stride (figures 2, 3 and 5). Horse displacement is smaller (P=0.000) than simulator, although a significant difference in variation between strides was not found. Simulator displacement is in the opposite direction to the horse. The horse moves upward and backward, then downwards and forward (clockwise) while the simulator moves upward and forward, then downward and backwards (anticlockwise) (figure 3).

Medio-lateral displacement of the simulator is smaller than the real horse (P=0.000) with less variability (P=0.004) presumably as a result of the simulators stationary nature. Despite the greater variation in a real horse, a clear and consistent pattern throughout the stride can be seen between left and right lead gallop (figure 4).

No significant difference in pitch amplitude was found although differences in phasing were visible between the simulator and real horse and also between left and right lead gallop (figure 6). In contrast a significant difference was found in roll amplitude (P=0.001) between simulator and real horse and a consistent but opposite movement was recorded between left and right lead gallop (figure 7).

Discussion

The racehorse simulator is a simplified model of the movement of a real horse. Powered by a 1.5kW (2 horsepower) motor, it is restricted mechanically due to hinged joints and its permanent location. A real horse's musculoskeletal system has a multitude of complex joints, muscles and tendons that all interact to support the horses mass and enable locomotion.

Displacement of the simulator sacrum is different to that of a real horse. The simulator has a smaller dorso-ventral and medio-lateral displacement in conjunction with greater cranio-caudal displacement amplitude compared to that of a real horse. Further to magnitude differences, phasing differs with the cranio-caudal displacement being around 180 degrees out of phase between the simulator and horse (figure 6) resulting in opposite trajectories. Due to the fixed nature of the simulator, and therefore inability to roll, a significant difference in sacrum roll was recorded between the simulator and real horse trials. Further differences were seen between left and right lead gallop initially rolling away from the side of the leading leg and then switching towards the lead leg around mid-cycle (aerial phase), again rolling away from the lead leg just before mid-stance (figure 7).

Displacement of the sacrum along all three axes were similar to those previously recorded in real horses (Pfau et al., 2006; Pfau et al, 2009) Table 2. Dorso-ventral displacement of the horse exceeds that of the simulator along with smaller cranio-caudal displacement. These differences are suspected to be a result of the fixed location and consistent, repetitive nature of the simulator. In contrast the real horse has gallop, an asymmetric gait, with an aerial phase that is constricted by the flight trajectory for any given height and distance with limited scope for caudal displacement during steady state gallop. This is also thought to be responsible for the additional work carried out by the jockeys when riding a real horse (Ille et al., 2015). Horses have a varied gait from stride to stride so jockeys must consistently interact with the horse to maintain harmonious movement. In contrast on the simulator the jockey can predict the movement as it remains constant and can therefore establish the most efficient technique. In further support of the predictable and repetitive nature of the simulator, the medio-lateral displacement is only 17mm compared to 61mm in the real horse allowing the jockey to establish a consistent rhythm. In contrast on the horse, jockeys have to account for larger sacrum roll and lateral displacements. The asymmetric nature of gallop, leads to further differences between and within cycles depending on the lead leg of the horse (figures 4 and 7). The horse displaces laterally and rolls away from the side of the lead leg during early stance. During the aerial phase the sacrum displaces and rolls towards the lead leg before returning during stance. None of these events are found on the simulator and therefore limits the real horse benefits of simulator riding. Cranio-caudal balance of the jockey could be aided by pulling on the reins and leaning on the neck – lateral balance is limited to pushing sideways with the legs, realignment of the head, changing the angle of the knee or differing forces in the stirrups, which themselves take fine motor control. A change in stirrup force symmetry to enable maintenance of jockey position is supported by the asymmetric forces seen during real horse riding. Sacrum pitch differs in phasing between the simulator and real horse (figure 6) but doesn't differ in amplitude unlike roll and displacement. In addition to differences in displacement and rotation magnitude between the simulator and real horse, there is more variation between strides across all parameters in the real horse requiring a more adaptable jockey.

While this study has shown significant differences in movement of a simulator compared to a horse the implications of these changes on jockey position and technique are not yet know. Changes in jockey kinematics are currently under investigation. The additional dorso-ventral displacement of the horse compared to the simulator implies jockeys may be better equipped to absorb the dorso-ventral impact of the horses' movement, by using their legs as a damper, if trained on real horses. However, the greater cranio-caudal displacement of the simulator suggests simulator training may better prepare the jockeys for perturbations such as a trip or buck. It may be that the accelerative and decelerative impulses within a cycle improve stability, reducing the risk of falls as seen with increasing experience (Hitchens et al., 2012). The apparent absence of medio-lateral displacement and roll on the simulator may leave a simulator trained jockey at increased risk from falls on a real horse due to lateral perturbations. Changes in direction and phasing of this lateral movement in the real horse, depending on lead leg, further complicate the transfer of benefits and training effects achieved using a simulator.

Arguably the most important difference is the timing of the dorso-ventral and cranio-caudal displacements. Not simply because they are the largest magnitude but also because they result in opposite trajectories. The simulator moving anticlockwise in contrast to the real horse which moves clockwise (figure 3) suggesting the movement specific muscle memory and fitness developed during simulator training may be of limited benefit, or possibly even detrimental, to the position specific training and fitness required on the real horse.

This study focusses on movement of the caudal part of the simulator and horse. More detailed analysis of trunk movement through an additional IMU attached cranially (such as on the withers) may further develop this knowledge.

Further work must now be carried out to look at the effect these kinematic differences have upon the position and movement of the jockey and the impact of jockey experience.

Conclusion

Movement of a racehorse simulator differs from that exhibited by a real horse. The simulator has a more consistent pattern with less dorso-ventral and medio-lateral but greater cranio-caudal displacement. Cranio-caudal displacement is also 180° out of phase. While still of great benefit from economic, safety, fitness and practical aspects, simulator training should be used with careful consideration of the potential for 'incorrect' movement and muscle memory that may be developed.

Acknowledgements

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Conflict of interest

There are no authors with any conflicts of interest relating to this manuscript.

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Tables

Table 1: Jockey Experience Categories.

Level	Name	Description
1	Beginner	Working full time for less than 1yr or possibly still at the BRS under Foundation Training.
2	Novice	Working full time for over 1yr but not had any race rides.
3	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.
4	Experienced	Riding over 3 years, has held licence for more than one year, had over 20 rides and ridden up to 20 winners raced 21 or more times and won 20 or less in the last year - corresponding to Apprentice Continuation Course.
5	Elite	Has held a licence for over 3 years, ridden over 20 winners and riding on a daily basis.

Table 2: Comparison between current sacral displacement amplitudes, mean (+/- SD) recorded on a real horse and racehorse simulator with those previously reported (Pfau et al., 2009). Values recorded in the current study are comparable to those previously reported while the values collected from the simulator are significantly different ($P<0.05$).

Displacement (mm)	Horse (2015)	Horse (2009)	Simulator (2015)
Horse Vertical	145 (14)	150 (8)	98 (6)
Horse Cranio-caudal	98 (20)	100 (7)	179 (12)
Horse Medio-lateral	61 (14)	60	17 (5)

Figure legends

Figure 1: Mean (+/- SD) dorso-ventral displacement during a single cycle for a single jockey showing greater mean (solid line) and standard deviation (dotted lines) in the real horse (blue) than on the racehorse simulator (cyan).

Figure 2: Mean (+/- SD) cranio-caudal displacement during a single cycle for a single jockey. Mean (solid line) and standard deviation (dotted lines) for a cycle showing the greater displacement and approximately 180 degree phase shift of the real horse (blue) compared to the simulator (cyan).

Figure 3: Left lateral view of the mean displacement trajectory for a single cycle from a single jockey on a single horse (blue) in a clockwise direction and the simulator (red) in an anticlockwise direction. * indicates mid stance (minimum dorso-ventral displacement) as used for cutting the data into strides.

Figure 4: Mean (+/- SD) medio-lateral displacement during a single cycle with a single jockey on a single horse (red and blue) compared to that of the simulator (cyan). A consistent but opposite mean (solid line) displacement pattern is recorded in the real horse during right (blue) and left (red) lead gallop.

Figure 5: Mean (+/- SD) displacement amplitudes of the horse (blue) and simulator (red) mounted sensor. Standard deviation bars demonstrate the more consistent movement of the simulator in both dorso-ventral (P=0.004) and mediolateral (P=0.004) directions.

Figure 6: Mean (+/- SD) pitch amplitude during a single cycle from a single jockey. Mean amplitude is greater on the simulator (cyan) compared to right lead (blue) and left lead (red) gallop in the real horse. A positive pitch indicates pitch down (caudal end up and cranial end down).

Figure 7: Mean (+/- SD) trunk roll on the simulator (cyan) and during right lead (blue) and left lead (red) gallop on a real horse for a single cycle from a single jockey. Virtually no roll occurs on the simulator while a consistent but opposite movement occurs during left and right lead gallop in the real horse. A positive roll indicates a roll to the right.

Figure 1

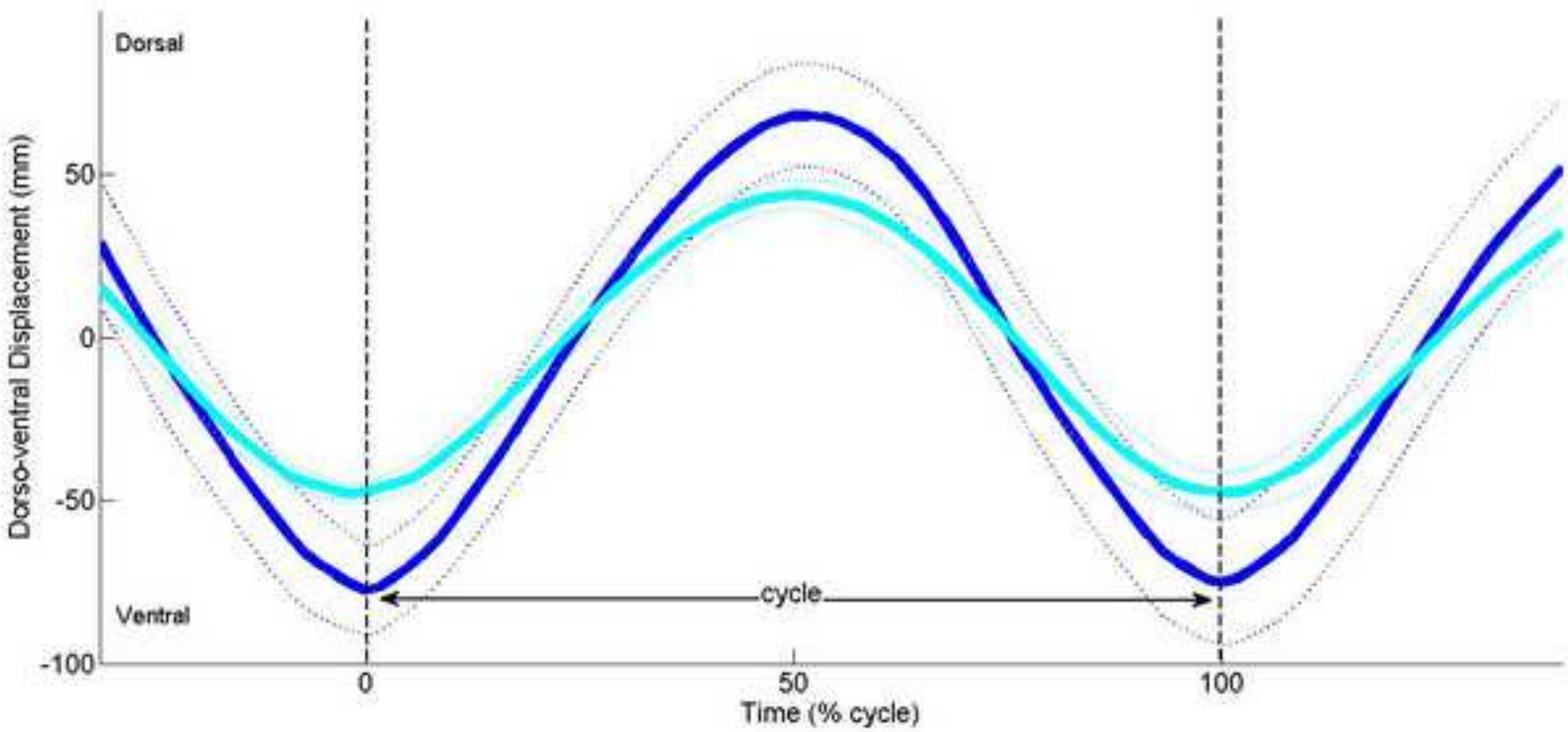
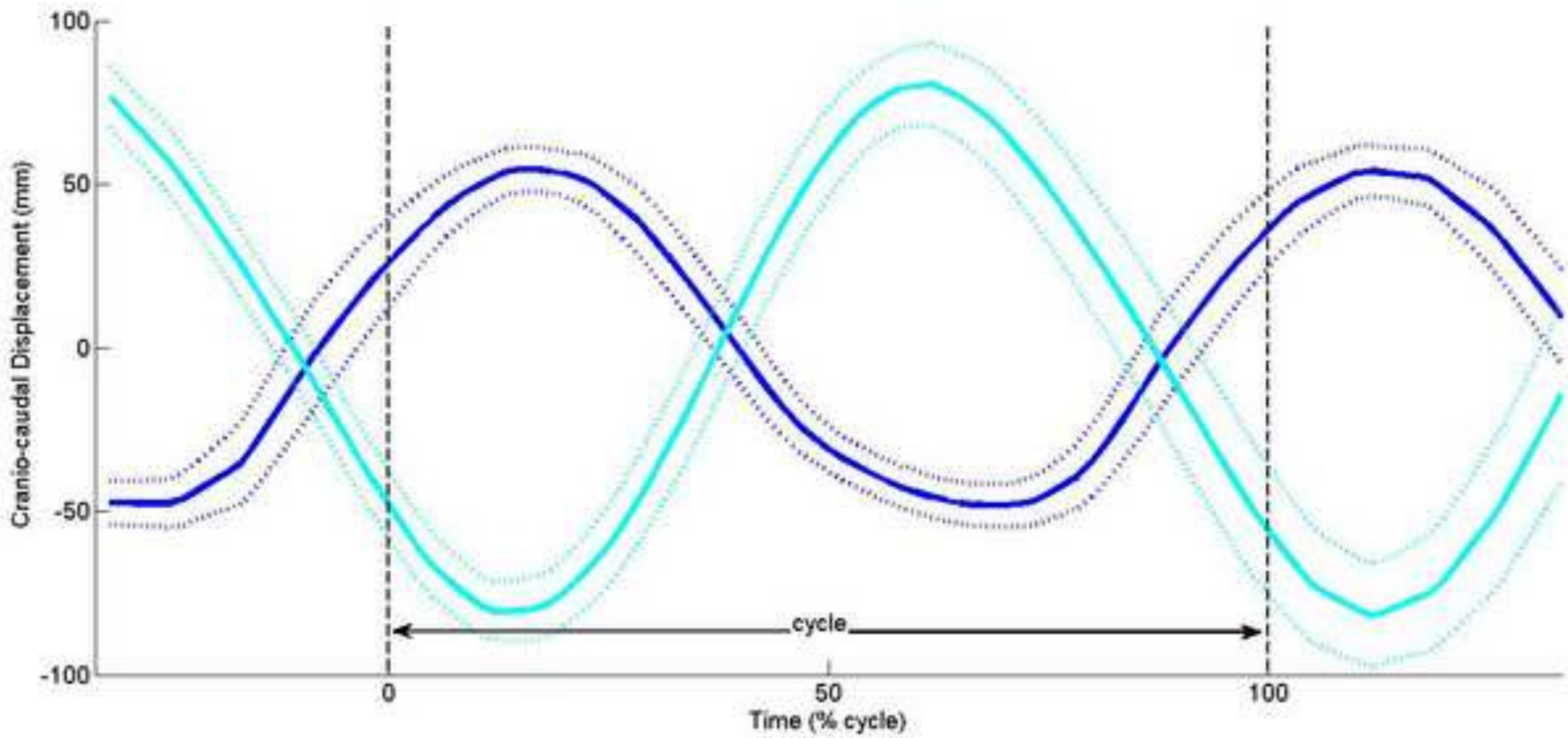
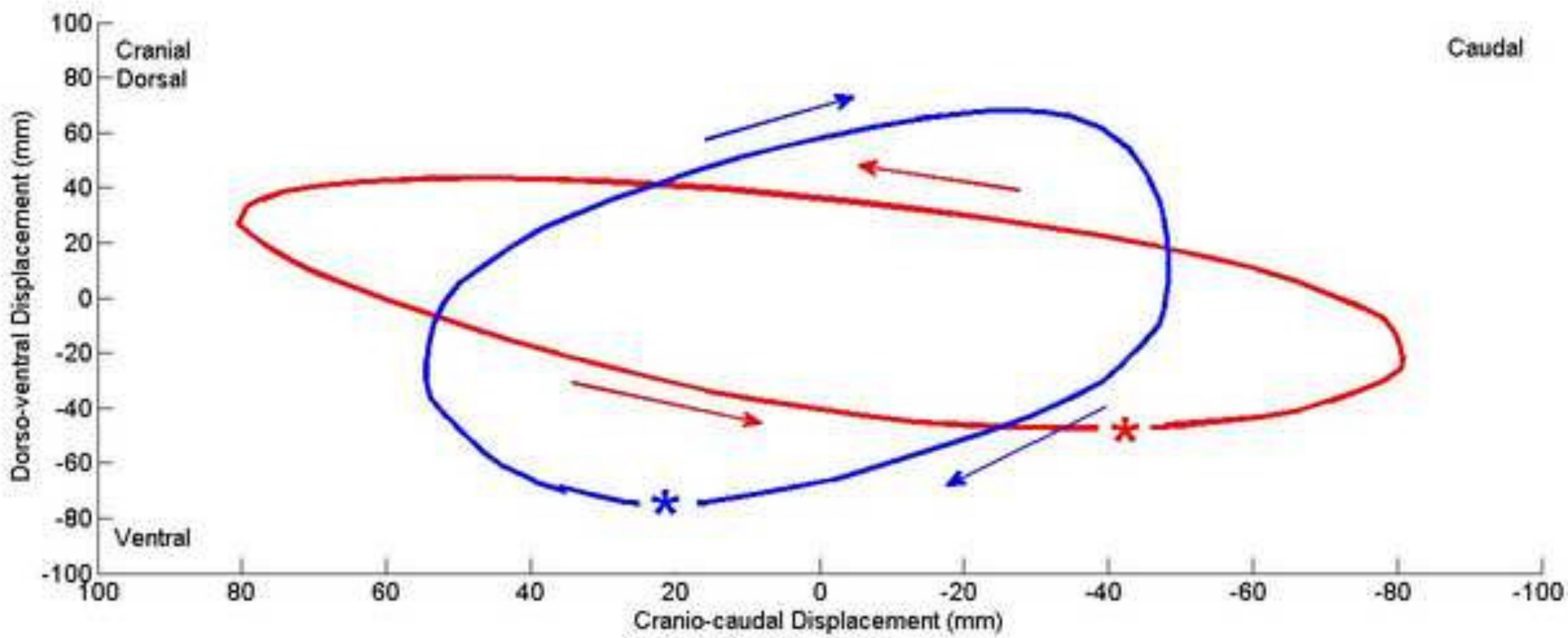

Dorso-ventral Displacement (mm)
50
0
-50
-100
Dorsal
Ventral
cycle
0
50
100
Time (% cycle)

Figure 2



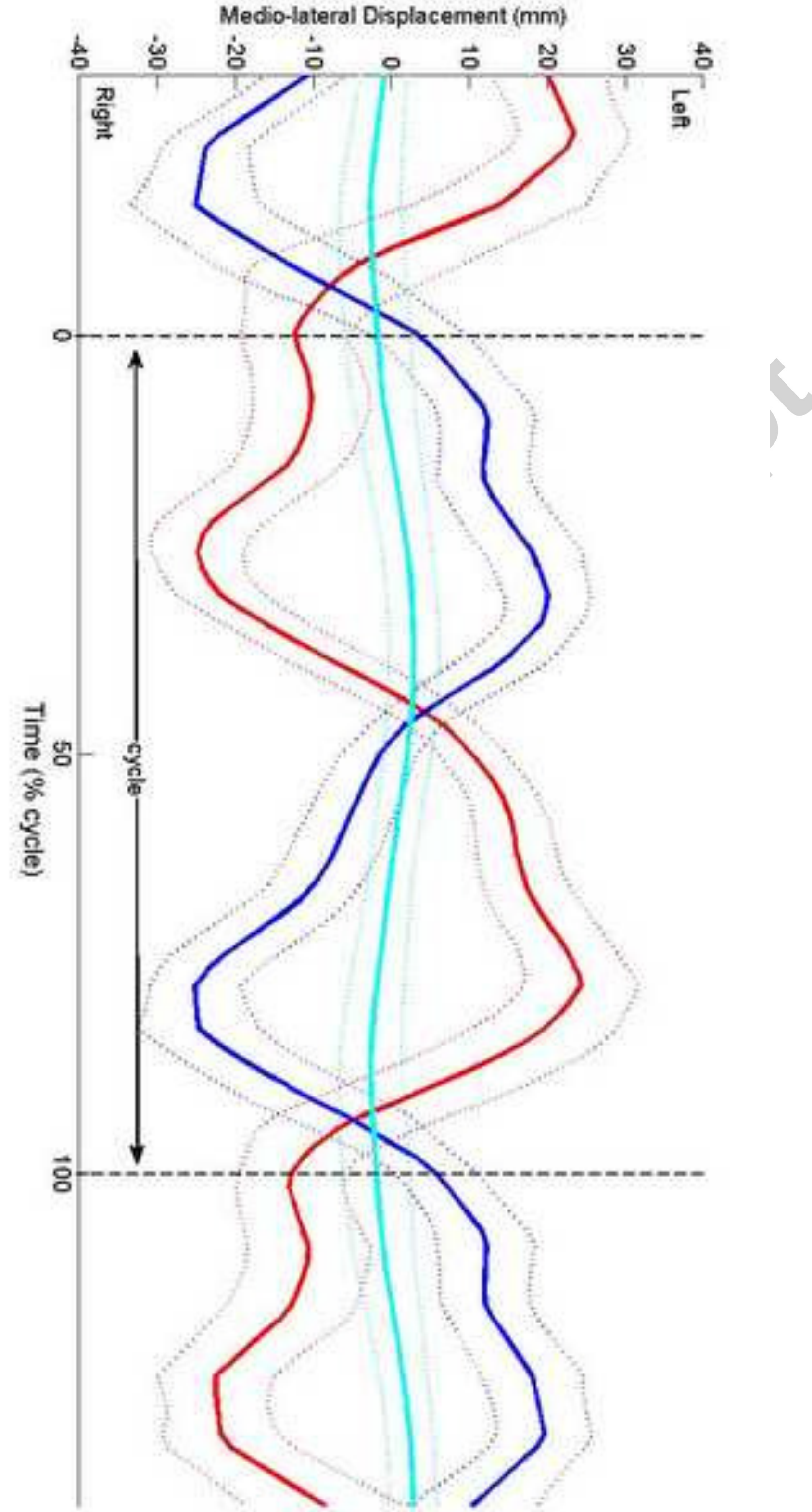
Cranio-caudal Displacement (mm)
100
50
0
-50
-100
cycle
0
50
100
Time (% cycle)

Figure 3



Dorso-ventral Displacement (mm)
Cranio-caudal Displacement (mm)
Cranial
Dorsal
Ventral
Caudal
100
80
60
40
20
0
-20
-40
-60
-80
-100

Figure 4



Medio-lateral Displacement (mm)
Left
Right
40
30
20
10
0
-10
-20
-30
-40
0
50
100
cycle
Time (% cycle)

Figure 5

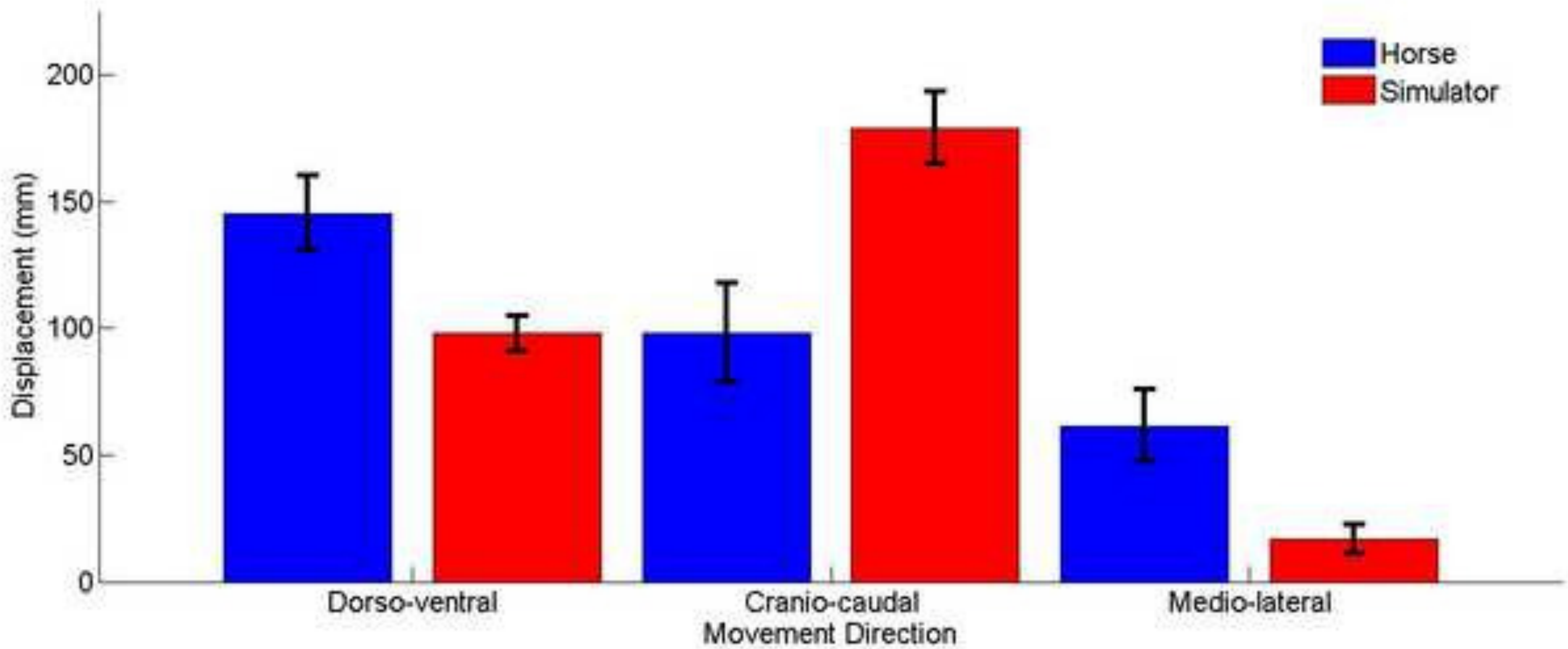

Horse
Simulator
Displacement (mm)
200
150
100
50
0
Dorso-ventral
Cranio-caudal
Movement Direction
Medio-lateral

Figure 6

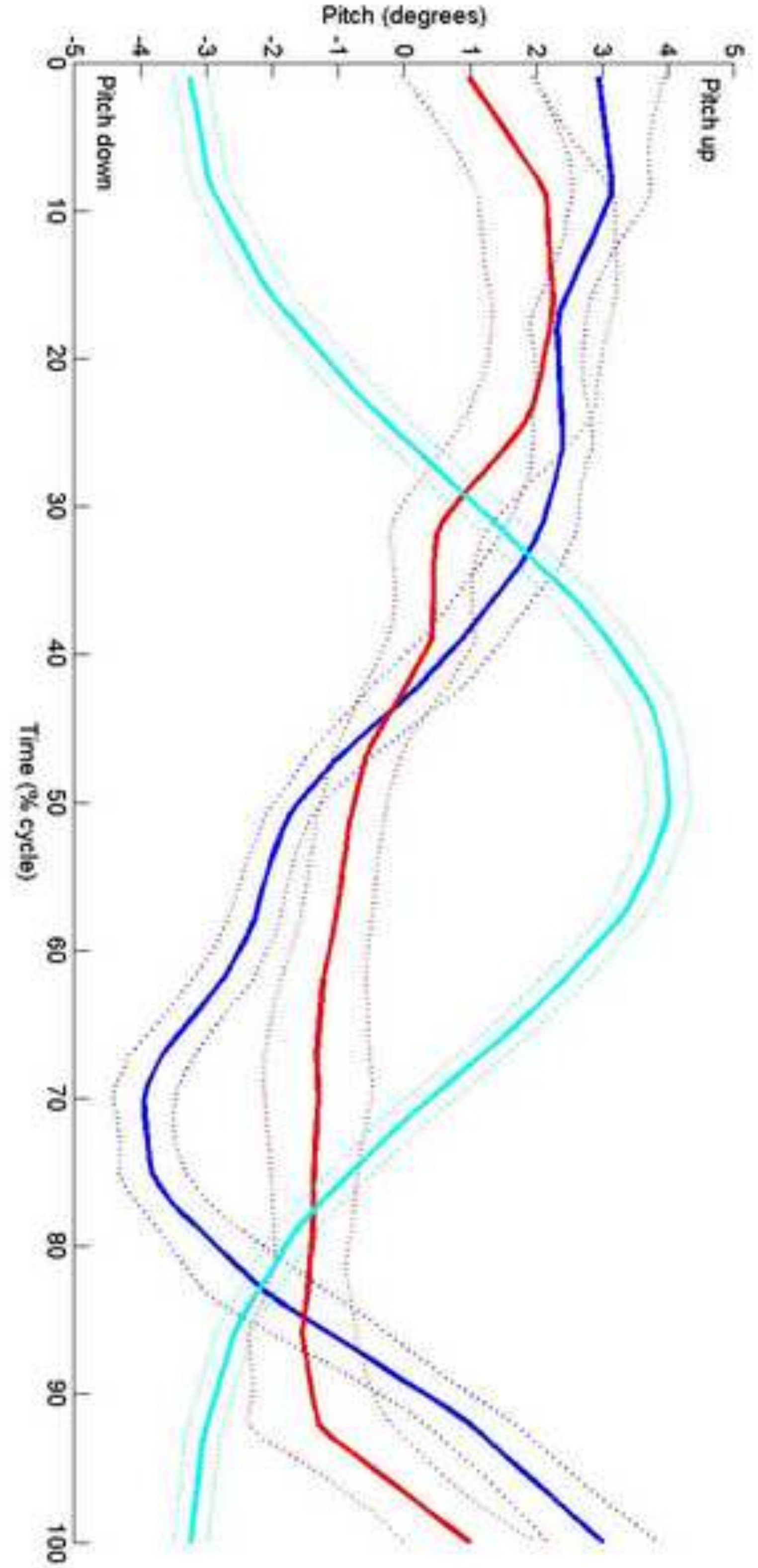
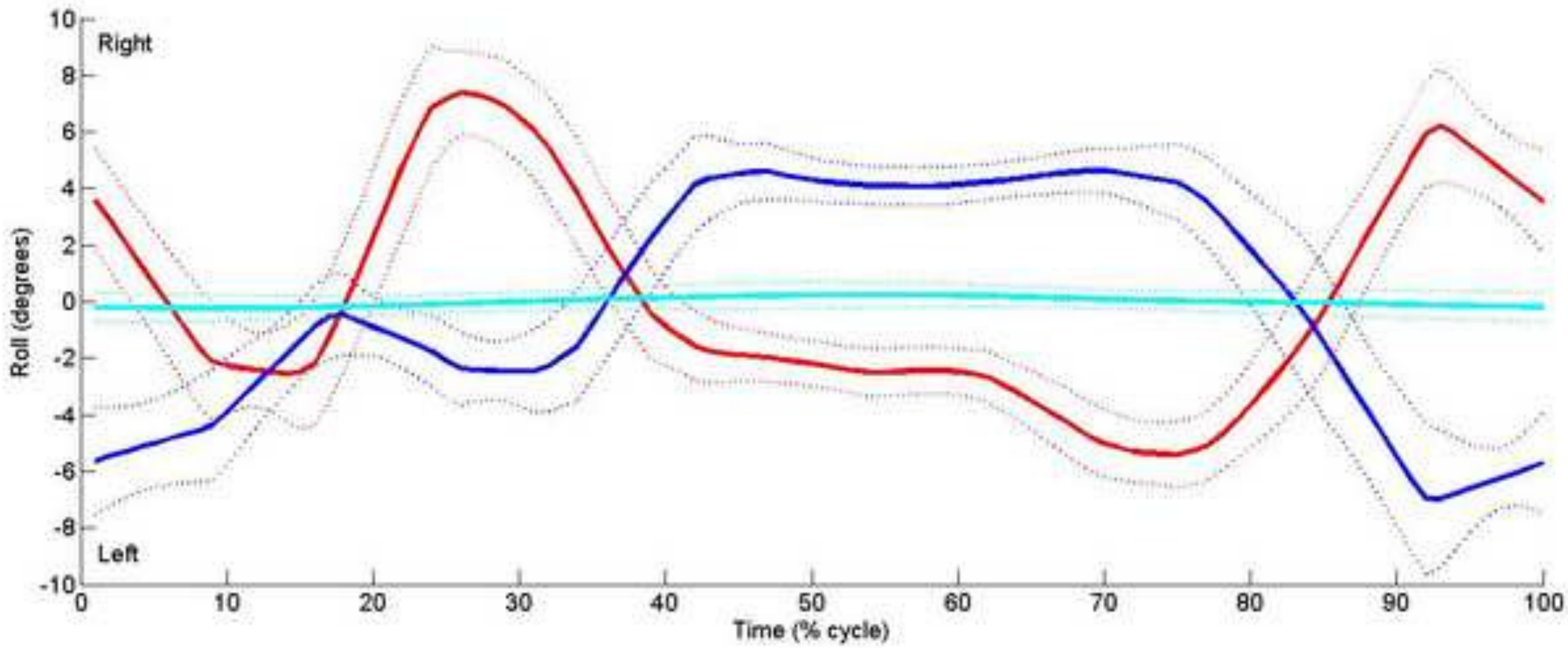

Pitch (degrees)
Pitch up
Pitch down
Time (% cycle)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
10
20
30
40
50
60
70
80
90
100

Figure 7


Right
Left
Roll (degrees)
Time (% cycle)
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
10
20
30
40
50
60
70
80
90
100