

## **A method of measuring the influence of rider interaction and training on the temporal relationships between limb cycles of horses using inertial motion sensors.**

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### **Take home message**

The affects of rider interaction and training on locomotor kinematic are potentially measurable using IMS, and information can be gained regarding changes in locomotor characteristics, this would provide an objective means of monitoring adaptive changes to training or recovery from orthopedic injury.

### **Introduction**

The detailed study of locomotion patterns is essential for assessing locomotor performance in the sports horse. It is of particular importance in evaluating training responses (Gaughan 1996; Miyata *et al.* 1999; Parsons *et al.* 2008), exploring subtle variations and fluctuations in gait, diagnosing lamenesses (Cheney *et al.* 1973), assessing horse rider interactions (Lagarde *et al.* 2005; Schollhorn *et al.* 2006), and investigating the effects of different training and competition surfaces (Burn and Usmar 2007; Cheney *et al.* 1973; Gustas *et al.* 2007; Thomason and Peterson 2008). All of which are critical factors that ultimately determine the locomotor performance of the horse. Hence there is a need to take locomotion analysis into the working/competition environment of the sports horse. The advancement of inertial based sensor technologies including accelerometers and gyroscopes present us with an opportunity to further investigate locomotion patterns within this working (field) environment.

Inertial motion sensor (IMS) studies on the temporal relationships between horses' limbs have been reported in literature (Parsons *et al.* 2008; Robilliard *et al.* 2007). Defining these temporal relationships has traditionally been based on the measurement of specific events within the limb cycle, for example initial ground contact of the respective limbs, with the gait being defined by the relative time lag between the limbs, and expressed by percentage of the stride duration relative to a given reference limb.

This characterization is based on an underlying assumption that the reference event occurs at the same stage within the respective limb cycles. This underlying assumption has yet to be demonstrated. However these techniques offer little information regarding the defining characteristics of the complete locomotor cycle, and the temporal inter-relationships that exist between the respective limb cycles.

Previous work has demonstrated that the a rider can influence the horses gait (Lagarde *et al.* 2005; Peham *et al.* 2004; Schollhorn *et al.* 2006) with a skilled rider having a stabilizing effect. However there is little known about whether the rider can alter the cyclical relationships between the limbs, particularly between the fore and hind limbs. Indeed anatomical and biomechanical differences between the respective fore and hind limb support an assertion that the respective limb cycles are likely to be different.

The aim of this study was to use IMS to define the entire limb cycle and to determine the temporal inter-relationships between the limbs for each gait of ridden horses under working/competition conditions.

## **Material and methods**

Trials were carried out with three horses training at Advanced British Dressage level or above. One rider, experienced at training up to Grand Prix level, was used with all horses to reduce variability. All trials were completed on the same day on a sand and rubber surface 20x60m arena.

In order to measure the rotations of each limb the horses were equipped with an IMS, containing a tri-axial 5 g accelerometer and three single axis 1200 deg/s gyroscopes, housed in adapted brushing boots. The rider wore a global positioning satellite (GPS) device fitted onto their riding hat to enable calculation of speed and stride length during working trials. The GPS device and the IMS were synchronized and time and date stamped by a computer previous to recording. To represent a real training situation, each horse was warmed up (WU) in walk, trot and canter to the rider's discretion. This was followed by approximately 20 minutes

of work (WK), consisting of collecting, working and extending gaits. The training sessions were filmed using a miniDV camcorder. The camcorder and the IMS designated as the reference limb were switched simultaneously to enable timed identification of transitions within, and between gaits.

Data from the z-axis gyroscope, recording the rotational velocities of the metacarpal/tarsal (MC/MT) region around the rotational axis of the carpal and tarsal joints, were used for analysis. A cross correlation approach was used to calculate the temporal phase-lag (TPL) between the cyclical wave forms of each limb with regards to a reference limb. The results were presented as a percentage of the stride duration of a reference limb.

## **Results and discussion**

Temporal stride data collected during symmetrical gaits from IMS attached to the MC/MT region of the horse differs from data collected at the level of the hoof, when comparing ipsilateral paired limbs. The fore limb (FL) rotation occurs at a different rate than the hind limb (HL), particularly in the preparation for hoof landing. This likely corresponds to anatomical and biomechanical differences between the FL and HL. However the 50% phase lag measured between contralateral paired limbs in symmetrical gaits was in agreement with previous studies (Abourachid 2003). The median TLP between limbs in walk, trot and canter is shown in Fig1.

For each gait the TLP altered to some extent between WU and WK trials for all 3 horses. The contralaterally paired limbs demonstrated a close coupling in TLP during the symmetrical gaits regardless of work type. This was not surprising as it is argued that characteristic time-lag reflects the underlying action of the central pattern generator (CPG) (Grillner *et al.* 2000; Williams *et al.* 1989) and that the contralateral pairs are activated as an antagonistic pair (Griffin *et al.* 2004). The TPL between ipsilateral/diagonal pairs in the symmetrical gaits reduced from WU to WK trials, most obviously for H1 and H2 (Fig2). During WU the FEI state that “horse is asked to progressively work with more engagement from the HLs and ‘lighten’ its forehand”. This may have the kinematic effect of causing the rotation of the FL in preparation for hoof landing to occur later in its cycle, and to become more closely synchronized with the HL rotation.

Asymmetries in TPL between diagonal pairs in trot were recorded for H1 and H2 during WU that reduced for H1 during WK and for H2 became almost symmetrical. H3 demonstrated symmetry in left and right

diagonal pairs for both WU and WK. This may be an indication of a stronger side in the individual horse and may demonstrate the usefulness of monitoring symmetry of gait as an early indication of compensatory movement (Keegan 2007).

During the working element of the trials, all horses altered the TPL particularly between the ipsilateral or diagonal FL and HL in a pattern that appeared to be dependant on stride length rather than stride duration or speed. The FLs had a greater range of TPL variation than the HLs in symmetrical gaits, and the amount of variation increased with training level.

### **Conclusions**

This novel method provides continuous information regarding the rhythm and regularity of the limb cycles of horses in a training environment. It enabling easy comparison for both inter and intra horse variations of gait, and the effect of different surfaces. The IMS system offers the potential to objectively assess limb cycle characteristics during lameness assessment, training or locomotory rehabilitation.

### **Reference list**

- Abourachid, A. (2003) A new way of analysing symmetrical and asymmetrical gaits in quadrupeds. *C R Biol* 326, 625-630.**
- Burn, J.F. and Usmar, S.J. (2007) Hoof landing velocity is related to track surface properties in trotting horses. *Equine and Comparative Exercise Physiology* 2, 37-41.**
- Cheney, J.A., Shen, C.K. and Wheat, J.D. (1973) Relationship of racetrack surface to lameness in the thoroughbred racehorse. *Am. J. Vet. Res.* 34, 1285-1289.**
- Gaughan, E.M. (1996) Skeletal origins of exercise intolerance in horses. *Vet. Clin. North Am. Equine Pract.* 12, 517-535.**
- Griffin, T.M., Main, R.P. and Farley, C.T. (2004) Biomechanics of quadrupedal walking: how do four-legged animals achieve inverted pendulum-like movements? 10.1242/jeb.01177. *J. Exp. Biol.* 207, 3545-3558.**
- Grillner, S., Cangiano, L., Hu, G.-Y., Thompson, R., Hill, R. and Wallén, P. (2000) The intrinsic function of a motor system -- from ion channels to networks and behavior. *Brain Res.* 886, 224-236.**

- Gustas, P., Johnston, C. and Drevemo, S. (2007) Ground reaction force and hoof deceleration patterns on two different surfaces at the trot. *Equine and Comparative Exercise Physiology* 3, 209-216.**
- Keegan, K.G. (2007) Evidence-based lameness detection and quantification. *Vet. Clin. North Am. Equine Pract.* 23, 403-423.**
- Lagarde, J., Kelso, J.A., Peham, C. and Licka, T. (2005) Coordination dynamics of the horse-rider system. *J Mot Behav* 37, 418-424.**
- Miyata, H., Sugiura, T., Kai, M., Hiraga, A. and Tokuriki, M. (1999) Muscle adaptation of Thoroughbred racehorses trained on a flat or sloped track. *Am. J. Vet. Res.* 60, 1536-1539.**
- Parsons, K.J., Pfau, T. and Wilson, A.M. (2008) High-speed gallop locomotion in the thoroughbred racehorse. I. The effect of incline on stride parameters. *J. Exp. Biol.* 211, 935-944.**
- Peham, C., Licka, T., Schobesberger, H. and Meschan, E. (2004) Influence of the rider on the variability of the equine gait. *Human Movement Science European Workshop on Movement Science* 23, 663-671.**
- Robilliard, J.J., Pfau, T. and Wilson, A.M. (2007) Gait characterisation and classification in horses. *J. Exp. Biol.* 210, 187-197.**
- Schollhorn, W.I., Peham, C., Licka, T. and Scheidl, M. (2006) A pattern recognition approach for the quantification of horse and rider interactions. *Equine Vet. J. Suppl.*, 400-405.**
- Thomason, J.J. and Peterson, M.L. (2008) Biomechanical and Mechanical Investigations of the Hoof-Track Interface in Racing Horses. *Veterinary Clinics of North America: Equine Practice Performance Horse Lameness and Orthopedics* 24, 53-77.**
- Williams, T.L., Grillner, S., V., S.V., Wallen, P., Kashin, S. and Rossignol, S. (1989) Locomotion in lamprey and trout: The relative timing of activation and movement. *J. Exp. Biol.* 143, 559-566.**