Determination of stride frequency using an accelerometer during equine locomotion

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INTRODUCTION:

Certain kinematic variables, such as stride length and stride frequency, are important when describing the gaits of a racehorse due to their clinical and performance related implications (Clayton 1993, Back et al 1995). The high numbers of biomechanic events that occur over a very short time lapse during equine locomotion make gait analysis difficult to identify using classic diagnostic techniques. Force shoes (Roland et al 2005) have been designed and used during high speed locomotion with varying success and force plates are limited to experimental tracks and rely on the subject hitting the plate with one leg (Witte et al 2006). High-speed cameras are the most frequently used method for kinematic analysis in horses, as they are precise and minimally invasive (Khumsap et al 2004). However, videographic techniques have their limitations as they require the inconvenience of following a large racehorse performing high-speed over-ground exercise over long distances. Therefore, a method of identifying kinematic parameters of racehorses, without discomfort to the animal, is needed.

Previously, limb-mounted accelerometers have been used in equine gait studies to measure stride frequency, stance duration, duty factor and protraction duration (Witte et al 2006, Parsons et al 2008) in an attempt to improve our understanding of the limb forces (Witte et al 2006) and gait transitions (Weyand et al 2000) that occur in animals. The advantages in using accelerometers are that they tend to be small, lightweight, robust and unobtrusive and are thus ideal for in-field monitoring. Parsons et al (2008) measured foot-on and foot-off times from galloping horses using a previously validated system of limb-mounted accelerometers. They found a mean increase in stride frequency from 2.10 to 2.17 strides s^{-1} at 12.5 m s^{-1} during level and incline galloping.

Global positioning system (GPS) technology has been used within the human physiology setting for the past decade as a means of analysing movement in a number of elite sports in an attempt to enhance performance. Based on signals sent from satellites, GPS units are worn by players during training and competition to collect real-time data such as speed, acceleration and distance (Larsson 2003). The use of GPS technology within the equine industry is limited, and has only involved the mounting of the device to the rider’s hat by means of a custom-made elasticated strap (Witte et al 2006, Parson et al 2008).

Advancements in equipment miniaturization have seen the recent emergence of integrated data loggers that combine for example accelerometer and GPS technologies. The assessment of ground impact combined with data related to speed and distance, has the potential to analyse gait kinematics in the field. Therefore, the aim of this study was to determine whether stride frequency in the gait of a thoroughbred racehorse could be accurately identified using an integrated data logger strapped to the horse’s torso. A high-speed camera was also used to validate the foot falls of the animal.
METHODS:

Two clinically sound thoroughbred racehorses of mean age 4 years, mean mass 510 kg (range 500-520 kg) and mean height 16.6 hh (range 16.2-17 hh) were used in the study. Each horse was equipped with a GPSports SPI Elite data logger (GPSports Systems, Canberra, Australia) mounted securely to their torso with accelerometer data sampled at 100 Hz in three axes.

Video data was taken using a digital video camera from the mid-sagittal view and captured at 25 Hz. The horses were placed on a treadmill for gait analysis and handled by their regular trainer to minimise the risk of injury. Both horses were familiar with galloping on the treadmill as they had completed numerous training sessions prior to the testing on a similar custom-made equine treadmill.

The horses were initially warmed up by walking and trotting at treadmill speeds of 15km/h for approximately one minute. They were then accelerated to canter over a few seconds, cantered at a steady speed of 32 km/h for approximately two minutes, before gradually accelerating to a gallop on a maximum treadmill speed of 50 km/h for 20 seconds. Accelerometer data was collected across all speeds but only analysed during the gallop exercise, which was approximately 20 seconds in duration per horse. Exercise duration was kept brief to ensure that the horse did not become fatigued during data collection, which could directly affect the results.

Video footage was digitised using HUMAN 2D video analysis software allowing for the acceleration of the horses’ lead leg to be calculated. Acceleration data from the GPSports units were downloaded and only vertical and horizontal data used for analysis.

RESULTS:

From the 10 strides analysed using the mounted accelerometer (Horse 1), the time between foot strikes varied between 0.51-0.54 sec. This value was very similar to that obtained from the video footage (0.48 sec). Further, there were clear spikes in the data that delineated foot strike both from the accelerometer and the video (Figures 1 and 2).

Data from the accelerometer suggests that the peak values can be used as indicators of foot strike. From these, a count function can be developed for a given epoch (possibly 5 sec) and the result combined with the displacement value from the GPS data to calculate stride length and stride frequency.
Figure 1: Vertical acceleration from GPS accelerometer

Figure 2: Vertical acceleration of the lead foot from video footage
DISCUSSION:

The aim of this project was to validate the identification of foot strike from accelerometer data within the GPSports data logger with video footage analysis. Through the identification of foot strike it was hypothesized that stride length and stride frequency could also be derived. The results show a clear indication of foot strike from the accelerometer (Figure 1) and this data corresponds to foot strike measured from the video footage (Figure 2).

The use of accelerometer data, rather than video footage or force platforms, allows a large volume of foot-fall data from limbs to be recorded accurately and efficiently during overground locomotion. This will give horse trainers the potential to monitor both training and race situations in an attempt to gather data on stride length, stride frequency, speed and distance covered. Further analysis of these variables may provide insight into changes in gait parameters occurring under fatigue and during differing sections of the track or race.

One limitation of this preliminary investigation is that it was only performed on a treadmill and studies have found that the locomotor patterns of horses are different when worked on a treadmill as compared to moving overground (Buchner et al 1993). For example, the duration of the support phase has been observed to be longer (Buchner et al 1993), the stride length shorter and the stride frequency higher when a horse is trotted on a treadmill compared to a racetrack (Fredricson et al 1983). Therefore, any extrapolation of gait parameters from horses moving on a treadmill to horses working on a track must be carefully considered.

Further analysis in this study should include the investigation of similar kinematic variables of a horse galloping at high speed under real-world, track conditions. Additionally, an algorithm needs to be developed in order to clearly differentiate single leg foot strike in the accelerometer data. This should also look to remove the surrounding noise that most commonly occurs during high speed activities. The data generated while galloping on a treadmill provides a consistent and repeatable large accelerometer impact strike, with the impacts for the other three limbs being discernible yet less pronounced (see Figure 1). This is ideal if an algorithm is to be developed that differentiates a single leg strike within each stride cycle. Whether this pattern is reproducible on a grass racetrack or with the accelerometer mounted in a different location on the horse remains unknown.

CONCLUSION:

The findings from this study provide a minimally invasive means of data collection and analysis in race horses in the field. The ability to determine foot strike from accelerometer data, combined with GPS derived speed and distance variables has the potential to allow gait analysis of racehorses to be carried out under high speed, real-world conditions.
REFERENCES:


