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Original Research

The Effect of Horse Velocity on the Output of an Inertial Sensor System

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ABSTRACT

Horse velocity has previously been demonstrated to influence both subjective and objective evaluation of lameness, especially in horses with mild lameness. As horse velocity is not always tightly controlled either within or between successive lameness examinations and horse-mounted sensor systems are becoming more commonly used in clinical practice, it is important to understand the influence of horse velocity on the results of these sensor systems. One inertial sensor (IS) system is widely available and commonly utilized to complement the subjective lameness examination. The objective of this study was to determine if horse velocity had an effect on the kinematic output from this commercial IS system. Twelve horses with at least one lame limb were examined with the IS system during a single daily high-speed treadmill exercise session. Horses were examined at the trot at 3.0, 3.5, and 4.0 m/s, in random order. Stride rate, maximum and minimum differences in head position (HDMax, HDMin), vector sum (VS), and maximum difference in pelvic position (PDMax) and minimum difference in pelvic position (PDMin) were analyzed using mixed-model analysis of variance with significance at $P < .05$. Horse velocity had a significant effect on stride rate ($P = .0025$) and one variable of hindlimb lameness (PDMin) ($P = .0234$). Horse velocity resulted in no significant differences on forelimb lameness kinematics (HDMax, HDMin, VS). Horse velocity may have an impact on assessment of hindlimb lameness as determined by this system, making it more important to control velocity in these cases.

1. Introduction

Lameness is one of the most common reasons a horse is examined by a veterinarian [1,2]. The subjective lameness examination is the most commonly utilized tool used to diagnose and monitor changes in lameness. However, the lack of well-defined lameness grading systems and the poor reliability of the subjective lameness assessment, especially in mildly lame horses, have emphasized the need for objective systems to supplement the subjective lameness examination [3,4].

Several objective systems are available to quantify equine lameness, including stationary force platform kinetics, optical kinematics, and horse-mounted inertial sensor (IS) systems. These systems have demonstrated accuracy in their ability to detect changes in gait associated with mild lameness [5–11]. One distinct advantage of horse-mounted IS systems, over stationary force platform and optical systems, is the ability to be easily used without a gait analysis laboratory. There is currently one commercial IS system (Lameness Locator, Equinosis LLC, St Louis, MO) that has begun to have widespread clinical use by an increasing number of equine veterinarians. Because of its

Animal welfare/ethical statement: All study protocols were approved by the Colorado State University Institutional Animal Care and Use Committee.

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widespread use, it is critical to understand any potential external factors that influence the output of this system.

Many factors can influence the assessment of lameness in horses, including horse velocity. The general recommendation for examining a lame horse is to trot the horse at a slow and consistent velocity [12–14]. In general, velocity is not quantified during a clinical lameness examination, and maintaining a consistent velocity throughout an examination can be challenging, as horses may increase their velocity in response to successful treatment or regional anesthesia [12]. Stride duration and rate have both been shown to be influenced by velocity [15]. The IS system does calculate stride rate, and thus, this system may be able to indirectly monitor horse velocity.

Several investigations have examined the effect of horse velocity on lameness assessment, both subjectively and objectively. One study demonstrated that horses were subjectively considered to be less lame as velocity increased [14]. Several other investigations documented a significant effect of horse velocity on objective methods of lameness detection using both stationary force platform and optical systems [12,15,16]. However, another investigation found no difference in output from an inertial measurement unit system at slow, preferred, and fast trotting velocities in a group of predominantly sound horses [14]. As horse velocity can change both intra-examination and interexamination, strict control over horse velocity can make data collection lengthy and can be difficult to tightly control when a horse is reassessed over months to years. Thus, it is critical to understand the influence of horse velocity on commonly utilized objective methods of lameness detection in order to make recommendations to either control or not control this variable.

The objective of this investigation was to determine the effect of horse velocity on the kinematic outcome parameters associated with forelimb and hindlimb lameness, as determined by the above mentioned, commonly used IS system. First, we hypothesized that changing horse velocity would result in significant differences in stride rate. Second, we hypothesized that horse velocity would have a significant effect on the kinematic variables of this system associated with both forelimb and hindlimb lameness, but it would not affect whether or not the lameness thresholds of these variables was reached.

2. Materials and Methods

2.1. Horses

Twelve Quarter Horse cross breeds between the age of 2 and 5 years were utilized for this study. There were six mares and six geldings, with mean (standard deviation) body mass of 432 kg (34 kg). All study protocols were approved by the Colorado State University Institutional Animal Care and Use Committee. These horses were part of a separate investigation examining cartilage healing within the femoropatellar joint, where cartilage defects were created on the medial trochlear ridge in both stifles. These horses had mild-to-moderate lameness, which had been surgically induced, in at least one hindlimb, and most horses also had mild-to-moderate unilateral forelimb lameness. All data collection was performed with horses during their normal exercise protocol on the high-speed treadmill. All horses had been previously trained to exercise on a high-speed treadmill (EquiGym High Speed Treadmill, EquiGym LLC, Lexington, KY) and received treadmill exercise 5 days a week. Horses were tied into the treadmill with straps attached to the left and right halter rings, and head movement was not restricted.

2.2. Subjective Assessment of Lameness

Prior to instrumentation and data collection, horses were assessed for lameness in a straight line over ground by the same examiner. A lameness grading scale modified from the American Association of Equine Practitioners lameness scale from 0 to 5 was used [17], and a lameness grade was assigned to each limb. Briefly, a grade 0 was not lame, grade 1 was an intermittent, inconsistently lameness at the trot, grade 2 was mildly, but consistently lame at the trot, grade 3 was moderately, but consistently lame at the trot, grade 4 was lame at both the walk and trot, and grade 5 was minimally to nonweightbearing lame at the walk. Half grades were utilized, when appropriate.

2.3. IS System

All horses had previously been instrumented with the IS system (Lameness Locator, Equinosis LLC) which consisted of three sensors. A uniaxial accelerometer was attached to a felt head bonnet with velcro tape (Dual Lock Tape, 3M, St. Paul, MN), a pelvic uniaxial accelerometer was mounted between the tuber sacrale using the same velcro tape and reinforced with duct tape, and a gyroscope was fastened by a pastern wrap to the right forelimb. In addition to the microelectrical-mechanical device (accelerometer or gyroscope), each sensor also contained a radio transceiver with antenna, a battery, and a microcontroller, which has been previously described [18]. Each sensor sampled at 200 Hz and communicated through wireless with a portable computer.

2.4. IS Variables

Kinematic variable calculation was determined by commercial software as previously described [18]. Briefly, stride number and rate were determined by the right forelimb gyroscope. The vertical displacement of the head and pelvis was determined by double integration of the accelerometer data using specially designed algorithms, which have been previously described [5,9,18]. Kinematic output variables examined from this IS system were stride rate, difference in maximum head position (HDMax), difference in minimum head position (HDMin), vector sum (VS), difference in maximum pelvis position (PDMax), and difference in minimum pelvis position (PDMin). HDMax, HDMin, PDMax, and PDMin are the calculated difference (mm) in the maximum or minimum head or pelvis position between the left and right portions of the stride during a single trot trial. For HDMax, HDMin, PDMax, and PDMin, a negative number indicated a left-sided lameness and a positive number a right-sided lameness. Vector sum was