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Original Research

The Use of Pressure Plates for Static Center of Pressure Analysis in Horses

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ABSTRACT

Stabilographic analysis allows the quantification of balance by tracking center of pressure (COP) displacements in the horizontal plane during quiet standing. The aim of this study was to use pressure plates to measure descriptive stabilographic variables in Puro Sangue Lusitano horses. Center of pressure data were measured in seven horses during quiet standing using two synchronized pressures plates. For each horse, three sets of five 8-second trials were recorded with 15-minute intervals between data sets. The exported COP coordinates were converted into global coordinates defined in a global reference frame from which stabilographic variables, namely craniocaudal (CC) and mediolateral (ML) COP amplitudes and velocities, resultant COP velocity, and total path length, were calculated. The results showed no significant differences between variables for the left and right limbs. Compared with the forelimbs, the hind limbs have significantly greater values for COP ML amplitude (forelimbs: 3.2 ± 1.1 mm; hind limbs: 2.5 ± 0.5 mm), COP CC velocity (forelimbs: 1.2 ± 0.2 mm/s; hind limbs: 2.1 ± 1.0 mm/s), COP ML velocity (4.3 ± 0.9 mm/s; hind limbs: 6.5 ± 2.3 mm/s), and path length (forelimbs: 49.8 ± 8.5 mm; hind limbs: 80.3 ± 31.4 mm). The greater stability in the forelimbs may be related to their strut-like function in controlling body movements, whereas the hind limbs show a more dynamic postural response. The pressure plates used in this study, which are relatively inexpensive and more portable than force plates, are a promising tool for performing stabilographic analysis in the field.

1. Introduction

The horse is in stable equilibrium when the center of mass (COM) is vertically above the base of support. Even during stable stance, however, the horse's COM is continuously moving at the microscopic level in a process known as postural sway. The movements are monitored by the proprioceptive visual and vestibular organs, and the information is used to generate appropriate muscular responses that adjust ground reaction forces (GRFs) to ensure that the COM remains within the base of support. The summation of the GRFs of all supporting hooves acts at the center of pressure (COP), and movements of the COP are indicative of postural control activity [1] that maintains the COM within narrow limits in a horizontal plane.

Posturography quantifies postural sway during standing. More specifically, stabilography measures the spatial and temporal characteristics of postural control. Excursions of the COP are visualized using stabilograms that show horizontal movements of the COP in craniocaudal (CC) and mediolateral (ML) directions over a period of time. The COP

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movements are described by stabilographic variables that are based on measurements of the amplitude, velocity, and frequency of COP motion [2].

In people, stabilography has been used extensively in studies of postural mechanics [3] and to quantify the effects on balance of factors such as age [4], athletic training [5], and visual deprivation [6]. It is also used diagnostically in assessing a variety of neurologic disturbances including Parkinson's disease [3], vestibular disease [7], and cerebral palsy [8]. Although stabilography has not yet been used extensively in quadrupeds, some applications in horses have been explored. Based on data from force platforms, equine stabilography has been shown to be a reliable technique, and agreement boundaries have been calculated [2]. These may be applied in detecting increased COP excursions associated with balance disturbances [9]. Normative values of stabilographic variables and their relationship with morphologic variables in adult horses have been reported [10], and the development of postural control in foals has been monitored by assessing changes in stabilographic variables from birth to 5 months of age [11].

The diagnostic applications of stabilography in veterinary medicine have been largely ignored although the technique has been applied to quantify disturbances in balance after detomidine administration [12] or when horses are deprived of visual input [13]. In a rehabilitation setting, stabilography was used to monitor improvements in balance after exercise on an underwater treadmill in horses with induced carpal osteoarthritis [14]. Stabilography may also have diagnostic value for distinguishing neurologic deficits from mild lameness. Horses with cervical stenotic myelopathy were found to have significant increases in COP range of motion and velocity measures [9].

Published studies of equine stabilography have been based on force platform data, and it has been shown that a single force platform recording data from both forelimbs or both hind limbs are representative of total body sway patterns, so a single force platform is adequate for stabilographic analysis [15]. Although the force platform is the gold standard for equine stabilographic analysis [2], its use is generally limited to a hospital or laboratory setting, which restricts the availability and applicability of the technique for practicing veterinarians. Pressure plates provide a portable and relatively inexpensive tool that can be used by an ambulatory veterinarian to measure the weight-bearing area of the hooves [16] and COP location beneath the hooves [16], as well as peak vertical force and vertical impulse [17] in hooves that contact the pressure plate simultaneously or consecutively during locomotion. They have also been shown to provide reliable data when quantifying temporal variables, including stance duration and time of occurrence of peak vertical force [18], and for measuring left-to-right symmetry ratios in a clinical setting [17]. Pressure plates have been shown to provide useful information in trotting horses on a stand-alone basis although vertical GRFs and impulses recorded with pressure plates are lower than those recorded simultaneously with a force plate [18], and dynamic calibration with a force plate yields better results [19]. In people, pressure plates are mainly used in patients who have difficulty traveling to a medical facility and have been used for balance assessment in patients with multiple sclerosis [20] and to assess plantar pressures in people with leprosy [21] and diabetes [22].

Pressure plates have been applied to evaluate load distribution across the hoof in horses walking and trotting on hard and soft surfaces [23] and to compare loading patterns in contralateral limb pairs [16]. However, the authors are not aware of the use of pressure plates in equine stabilography. Therefore, the objectives of this study were, first, to use pressure plates for stabilographic analysis in horses and, second, to report descriptive stabilographic variables measured using pressure plates in horses.

2. Materials and Methods

The protocol was approved by the Veterinary College Ethical Use Committee of Universidade Lusófona de Humanidades e Tecnologias (process 1/2011).

2.1. Horses

Seven clinically sound Puro Sangue Lusitano (PSL) horses (four stallions, one gelding, and two mares), aged 4–9 years (mean ± standard deviation [SD], 5.6 ± 1.8 years), and with body mass of 441–569 kg (mean ± SD, 502.1 ± 44.0 kg) were used. Mean height at the withers was 158.7 ± 6.0 cm, and the mean distance between forelimbs and hind limbs was 110.6 ± 6.0 cm. All horses were ridden regularly for recreational purposes.

2.2. Measurement System

Data were collected with two pressure plates (Footscan; RSscan International, Olen, Belgium) with data collections being triggered simultaneously which was shown to synchronize the recordings within ±0.02 seconds. Each pressure plate has a measuring surface of 1,068 × 418 mm, with a pressure sensitive area of 975 × 325 mm instrumented with 8192 polymer resistive sensors arranged in a matrix of 128 × 64 sensors. This provides an average sensor density of 2.59 sensors/cm^2 and a sensitivity of 0.27 up to 127 N/cm^2. The two plates were connected to separate laptops equipped with Footscan Balance 7.7 Second Generation (RSscan International) software, sampling at 50 Hz. At this sampling rate, data could be collected for up to 10 seconds. Calibration of the pressure plates was performed according to the manufacturer's instructions by having a person weighing 1,030 N stand on the pressure plate before each measurement session. The calibration was performed with the rubber mats in place so that after calibration pressure was zero with the rubber mat in place.

2.3. Data Collection

All horses were determined to be free from lameness and neurologic impairment by an experienced veterinarian. The hooves had been regularly balanced and trimmed by an experienced farrier. Before data acquisition, each horse was familiarized with the testing environment and protocol. The horses stood in a square position, with the hind limbs on one pressure plate and the forelimbs on the second