Strain gauge measurement of rein tension during riding: a pilot study

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Abstract
A pilot study was performed using a strain gauge transducer intercalated between the bit and the left rein to measure rein tension dynamically during riding. The strain patterns consisted of a series of spikes with frequencies corresponding to two per stride in walk and trot and one per stride in canter. The highest tension recorded in each gait was 43 N at walk, 51 N at trot and 104 N in canter. Based on the results of this study, it is recommended that the methodology should be adapted so that both reins are instrumented simultaneously, data are transmitted telemetrically to eliminate the need for a tether connecting the horse to the computer, and kinematic data are synchronized with the rein tension recordings.

Keywords: equestrian; transducer; horseback riding

Introduction
During horseback riding one of the methods of communication between rider and horse is through the reins and their connection to the bit that lies within the horse’s oral cavity. Tension on the reins applies pressure to the oral tissues, and the horse is trained to yield in response to this pressure. Measurements of rein tension could be applied to compare tension profiles of riders with different levels of expertise with the goal of understanding and improving equestrian technique. Longitudinal studies of horses and riders would yield information about changes in the magnitude and pattern of rein contact with level of training. Excessive tension in the reins may injure the oral tissues, but the magnitude of rein tension at different gaits and during different activities has not been well documented. A German study reported the use of a strain gauge transducer to measure rein tension at walk, trot and canter, but the sensor and its battery were too heavy to be used in both reins simultaneously. The present article describes a pilot study, performed as part of an MS thesis, that applied strain gauge transducers for dynamic measurement of rein tension during horseback riding. The objective was to identify a suitable sensor and develop a practical measurement system that could be used in the field for recording tension in left and right reins simultaneously. The availability of such a system would facilitate advances in understanding the action of the reins, the rider’s technique and the horse’s response to rein tension.

Methodology
The study was performed under the auspices of the University Committee on Research Involving Human Subjects and the All University Committee for Animal Use and Care. The rider provided written informed consent.

The first challenge was to select an appropriate transducer that would be sufficiently accurate and sensitive across the range of tension generated in the reins during the normal range of riding activities. The sensor was also required to be small in size and light in weight so that it did not interfere with the normal movements and functions of the reins.

The MLP sensor series (Transducer Technologies, Temecula, CA) includes a range of sensors of different capacities that are lightweight with high resistance and good accuracy. For this pilot study, the MLP-300 was
selected. This sensor weighs 85 g, is accurate up to 1334 N and can withstand 2002 N. This was considered to allow a large margin of safety for a pilot study.

Although the ultimate goal is to develop a data-collection system with two sensors, one on each of the left and right reins, a single sensor was purchased for the pilot study and it was used on the left rein. The MLP-300 sensor was inserted between the bit and the rein using braided wire secured with a clamp (Fig. 1). The sensor was tethered to a signal-processing unit (Vishay Measurements Group P-3500 Strain Indicator, Raleigh, NC) using a 10 m long, unshielded, eight-strand cable (Belden-M9421 CMG 8C22, Las Vegas, NV). Four strands were used: two provided excitation voltage (2 V direct current) and two transmitted the change in output voltage (ΔV) in response to the load acting on the left rein. The signal-processing unit was set in a full bridge configuration with 1 × amplification. It was connected to a 12-bit analogue-to-digital board (National Instruments DAQ CARD™-700, Austin, TX) located inside a laptop computer (Toshiba Satellite 2535 CDS, New York, NY) using BNC cables. Data were sampled at 1000 Hz.

The sensor was calibrated with all cables and attachments prior to data collection by recording the voltage changes when known weights were suspended from it. A calibration device was constructed consisting of a tripod from which the sensor and weights could be suspended. Ten weights were used that allowed calibration in the range 0–22 kg. The regression calculation from the calibration was used to establish the accuracy and linearity of the system.

One of the goals of the pilot study was to determine the range required for a transducer used to measure rein tension during normal riding activities. This implies estimating the likely maximal tension that will be encountered. Thus, a horse was chosen that was notorious for leaning hard against the reins. The rider was an experienced competition rider and she was instructed to ride strongly and accept as much tension on the reins as the horse would offer. The horse wore his usual bridle with a jointed snaffle bit.

During data collection the signal processing unit and the laptop computer were placed on a cart in the centre of a riding arena. Power was supplied via a cable buried beneath the sand footing. The wires leading to and from the sensor were taped to the left rein and then to the rider's waist, so their weight was supported by the rider and not by the rein. The part of the cable that extended from the rider's waist to the computer was carried by an assistant to prevent it dragging on the ground. The horse was ridden in circles around the computer in clockwise and counter-clockwise directions at walk, trot and canter (Fig. 2).

Data were displayed on the screen of the laptop in real time and were stored on the hard drive using custom software. Data collections were made for 5 s periods at each gait using a sampling frequency of 1000 Hz. The frequency content of the signal was analysed and used to select an appropriate filter frequency (8 Hz) using a Butterworth digital filter.

Results

The sensor calibration indicated a linear response throughout the calibration range. During data collection, the rider perceived a high but consistent rein tension. The data, however, showed a pattern of spikes at all gaits (Fig. 3) that occurred with consistent frequencies of 108 per minute at walk, 168 per minute at trot and 90 per minute at canter. The maximum values of the rein tension peaks ranged from 4 to 43 N at walk, 19 to 51 N at trot and 21 to 104 N at canter.

Discussion

The jointed snaffle bit used in this study is generally regarded as a relatively mild bit in terms of its effect on

[Fig. 1] Strain gauge transducer (MLP-300) inserted between the rein shown on right and a clip for attachment to the ring of the bit shown on left

[Fig. 2] Horse being ridden on a circle around laptop computer with strain gauge transducer intercalated between bit and left rein. Assistant on foot is carrying a cable that supplies power to the transducer and transmits data to the laptop computer.
the horse. Horses tend to accept more tension when ridden in a mild bit than when ridden in a more severe type of bit. The rider was instructed to accept as much tension as the horse offered, so the values recorded probably represented more tension than an experienced rider would generate when riding normally on this horse. However, these values are generally similar to those reported in a German study of 30 N at walk, 80 N at trot and 60 N at canter. The highest tension recorded in this study was 104 N at canter. Even higher tension may be anticipated when galloping or jumping in an outdoor environment, so a sensor suitable for measuring rein tension during outdoor riding should withstand higher tension than recorded here. These data will provide guidelines for selecting appropriate transducers in future studies.

The tether from horse to computer did not pose a problem since the horse used in the study was accustomed to being longed. However, the need to maintain a circular pattern was inconvenient and it is likely that rein tensions are different when the horse is turning than when moving on a straight line. The availability of telemetry would greatly increase the scope and applications of the system.

A similar system for recording rein tension used a heavier sensor (300 g), and had the battery and circuitry located on the rein. The weight of the equipment restricted the researchers to using a gauge on one rein only, rather than instrumenting both reins. In the study reported here, the sensor weighed only 85 g, and the peripheral devices other than the sensor itself were located at sites distant from the rein. Consequently, the instrumentation on the rein was much lighter in weight, making it feasible to instrument both reins simultaneously. The presence of transducers on both reins is preferable since it allows evaluation of asymmetries associated with handedness of the rider, sidedness of the horse and the left–right asymmetry inherent in canter and gallop. It would also facilitate detection of differences between the inside and outside reins when moving through a turn or performing lateral movements. Coordination between the left and right reins will become evident when bilateral rein data are available.

An intermittent pattern of rein tension with spikes at regular intervals was also reported by Preuschoft et al. The frequency of the tension spikes varied with the horse’s gait. Other studies have reported average stride frequencies of 55 strides min⁻¹ for walk, 79 strides min⁻¹ for trot and 99 strides min⁻¹ for canter. Allowing for individual variation associated with horse size, the frequencies of the tension spikes recorded in this study suggest that there are two spikes per stride at walk and trot and one spike per stride at canter. A method of correlating kinematic events in the stride cycle with changes in rein tension would undoubtedly aid in understanding how the tension spikes are generated.

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**References**