Electromyographic activity of the longissimus dorsi muscles in horses during trotting on a treadmill

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Objective—To use electromyography (EMG) to measure physiologic activity of the longissimus dorsi muscles of horses during trotting on a treadmill.

Animals—15 adult horses (5 to 20 years old that weighed 450 to 700 kg) that did not have clinical signs of back pain.

Procedure—Data were recorded for each horse during trotting on a treadmill at speeds of 2.6 to 4.4 m/s. Surface electromyography was recorded bilaterally from the longissimus dorsi muscles at the levels of T12, T16, and L3.

Results—In each motion cycle, 2 EMG maxima were found at the end of the diagonal stance phases. The EMG activity peaked slightly later at L3 than at T12 and T16. Maximum EMG amplitudes were highest at T12 and decreased caudally, with mean ± SD values of 4.51 ± 1.20 mV at T12, 3.00 ± 0.83 mV at T16, and 1.78 ± 0.67 mV at L3. Mean minimum EMG activity was 1.30 ± 0.63 mV at T12, 0.83 ± 0.35 mV at T16, and 0.80 ± 0.39 mV at L3. The relative amplitudes (ie, [maximum – minimum]/maximum) were 67 ± 11% at T12, 66 ± 8% at T16, and 71 ± 8% at L3.

Conclusions and Clinical Relevance—Activity of the longissimus dorsi muscles is mainly responsible for stabilization of the vertebral column against dynamic forces. The difference between minimum and maximum activity may allow application of this method as a clinical tool. Data reported here can serve as reference values for comparison with values from clinically affected horses. (Am J Vet Res 2004;65:155–158)

During the past several decades, back pain and diseases of the vertebral column and spinal cord have become recognized as important, often performance-limiting orthopedic problems in horses. In addition to clinical examination, several diagnostic methods (eg, scintigraphy, radiography, and ultrasonography) have been used for the investigation of the back of horses; however, investigation of functional deficits in vivo remains unrewarding. Electromyography (EMG) is now widely accepted as an important tool to investigate muscle function in horses, and several studies17 have involved the use of invasive and noninvasive EMG techniques. The EMG activity of the back muscles of horses has been reported at stance during induced flexions19 and during trotting. However, the use of EMG in clinical situations has been limited, mainly because of the large variability of results.18

The objective of the study reported here was to measure activity of the longissimus dorsi muscles in trotting horses by use of surface EMG at 3 locations and determine the difference between maximum and minimum activity to establish a database that can be used as reference values. The hypothesis tested was that horses without clinically detectable back problems would have similar characteristics of the surface EMG for the longissimus dorsi muscles during 1 motion cycle when trotting on a treadmill and that the maximum EMG activity of the longissimus dorsi muscles for each horse would reflect the minimum EMG activity of that horse.

Materials and Methods
Animals—Fifteen horses (4 mares, 2 stallions, and 9 geldings) comprising 9 Warmbloods, 4 Standardbreds, and 2 Haflingers were used in the study. The horses were 5 to 20 years old and weighed 450 to 700 kg. The horses were part of a university herd that was used for teaching and experimental purposes. Horses were trained to trot on a treadmill in accordance with described training procedures.

Data collection—Measurements were obtained by use of an EMG telemetric system20 (sample frequency, 1.2 kHz) in combination with a simultaneously triggered system for kinematic motion analysis21 (6 cameras; sample frequency, 120 Hz; resolution, 240 x 833 pixels).20 To identify motion cycles, semispherical markers were placed on the lateral hoof wall of each hoof of all horses.

The skin dorsal to the longissimus dorsi muscles was shaved, and surface EMG electrodes were positioned bilaterally over the longissimus dorsi muscles at the level of the dorsal spinous processes of T12, T16, and L3. The distance between the bipolar electrodes was selected on the basis of the EMG guidelines.20 Surface electrodes were affixed to the skin with nonirritant adhesive.

Horses completed at least 3 training sessions during a period of 2 or more days. Each horse trotted at its own optimum speed,22 which was determined during the last training session. The horses were allowed to warm up by trotting on the treadmill for approximately 5 minutes before measurements were obtained. Measurements were obtained during an experimental period of 10 seconds, and 2 experiments were conducted for each horse, resulting in a minimum of 13 motion cycles/horse. The EMG data were transmitted to a computer by a telemetry system.

Signal processing—The EMG signal was rectified and sampling rate reduced to 120 Hz to make motion and EMG comparable. This undersampling technique was achieved by calculating the mean of 10 samples. The final step in the calculation was the application of a Butterworth lowpass filter (fifth order; cutoff frequency, 10 Hz). For all the motion cycles measured, the mean EMG and mean motion for a motion cycle were calculated for each horse (Fig 1).

The 3-dimensional coordinates of each marker during the time course of each experiment were calculated from...
the video data. These time series were then smoothed by use of a Butterworth lowpass filter (cutoff frequency, 5 Hz). Duration of the motion cycle was calculated from the movement of the hoof of the left forelimb. At all 3 locations, the relative amplitude in percentage (RA%), which represented the percentage difference between minimum and maximum muscle activity, was calculated by use of the following equation:

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RA\% = \frac{\text{maximum} - \text{minimum}}{\text{maximum}}
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Statistical analysis—Normal distribution of data was tested by use of a Kolmogorov-Smirnov test. A 1-way ANOVA was performed to test for differences between maximum muscle activities and RA% at each of the 3 locations. Differences between muscles (left and right) were tested by use of a Student t test for paired samples. Values of \( P \leq 0.05 \) were considered significant.

Results

Results of the study were recorded. Maximum EMG amplitudes were highest at T12 and decreased in the more caudal locations (Table 1). In the 15 horses, the maxima ranged from 2.41 to 7.62 mV at T12, 0.86 to 5.15 mV at T16, and 0.73 to 4.38 mV at L3. The minima ranged from 0.08 to 2.32 mV at T12, 0.32 to 2.03 mV at T16, and 0.15 to 1.33 mV at L3.

For each motion cycle, 2 EMG maxima were found at the end of the diagonal stance phases. The larger maximum was detected simultaneously with take off of the ipsilateral hind limb, and the smaller maximum was detected simultaneously with take off of the contralateral hind limb (Fig 2).

Muscle activities differed significantly \( (P = 0.01) \) among the 3 locations; however, we did not detect significant differences for RA% at the 3 locations. For the 15 horses, RA% at T12 ranged from 53% to 85% (mean ± SD, 66 ± 8%), whereas RA% at T16 ranged from 54% to 84% (mean ± SD, 71 ± 8%), and RA% at L3 ranged from 48% to 84% (mean ± SD, 67 ± 11%).

We did not detect significant differences in muscle activity between the left and right sides. However, as a result of their dependence on the motion cycle, there was a phase delay between left and right maxima and minima of 50% of the duration of the motion cycle.

In the horses used for this study, speed on the treadmill was not significantly correlated with EMG peak values or localization of the EMG peak values within the motion cycle. Also, EMG peak values were not significantly correlated with the body weight of each horse.

| Table 1—Mean ± SD values for the first and second maxima and minima of electromyography (EMG) activity of the longissimus dorsi muscles measured at 3 locations in 15 horses during trotting on a treadmill |
|-----------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Variable        | T12         | T16         | L3          | T12         | T16         | L3          |
| Maximum         |             |             |             |             |             |             |
| 1               | 3.24 ± 1.06 | 2.03 ± 0.63 | 1.43 ± 0.59 | 72 ± 24     | 45 ± 14     | 32 ± 13     |
| 2               | 4.51 ± 1.20 | 3.00 ± 0.83 | 1.78 ± 0.67 | 100 ± 27    | 67 ± 18     | 39 ± 15     |
| Minimum         |             |             |             |             |             |             |
| 1               | 1.30 ± 0.63 | 0.83 ± 0.35 | 0.80 ± 0.39 | 29 ± 14     | 18 ± 8      | 18 ± 9      |
| 2               | 1.78 ± 0.58 | 0.95 ± 0.47 | 0.72 ± 0.38 | 40 ± 13     | 21 ± 10     | 16 ± 9      |

RA% = Relative amplitude in percentage.
Discussion

Surface EMG was selected for the study reported here because it is noninvasive, does not cause pain, and is reliable. Increased recording noise among muscles can be a relevant problem in surface EMG of small, closely related muscles. However, in our study, this was negligible as a result of the high EMG activity of the large muscles during trotting. Increased recording noise can be reduced through adequate skin preparation and suitable filtering techniques.24

Skin movement is an inherent problem of surface EMG, especially in regions with loose skin or in extremely mobile regions. In our study, the effect of skin movement on the EMG measurements was not quantified because the back of horses has a tight skin covering and the overall mobility is low.25

Onset of the EMG signal in the motion cycle was similar to described EMG patterns of the longissimus dorsi muscles during trotting.26 The course of EMG activity during the motion cycle while trotting was determined more precisely in our study, compared with results in other studies810 in which only onset of EMG and the integrated EMG was determined. In the study reported here, 2 maxima and minima were assessed in each motion cycle and 3 locations of the left and right longissimus dorsi muscles were used. This provided relevant information about muscle activity during the stance and swing phases as well as information about the left and right lateral distribution of EMG activity.27

In contrast to results of another study,8 we did not detect dependence of EMG values of the longissimus dorsi muscle on speed of the horses on the treadmill. These results may not be contradictory because the dependence on speed in that other study was documented within horses, whereas dependence on speed in our study was tested among horses.

Activity of the longissimus dorsi muscles is probably mainly responsible for stabilization of the vertebral column against dynamic forces. This could explain the reason that EMG activity at L3 was less than at T12 or T16 in 8 of 15 horses because the passive flexibility of the lumbar vertebrae is smaller, compared with that of the thoracic vertebrae.28 It is also possible that the smaller EMG activity was attributable to the opposite movements of the hind limbs or the close proximity of the L3 region to the sacral bone, as suggested in another study.8 However, muscle force cannot be directly correlated to EMG activity, and further studies are needed to confirm this interpretation.27

During take off of a hind limb, EMG activity of the longissimus dorsi muscle ipsilateral to that limb is higher than EMG activity of the contralateral longissimus dorsi muscle, which is attributable to the propulsive force generated by the hind limb. Maximum EMG activity precedes the maximum vertical excursion, which can be interpreted as preemptive tension.

The range of relative EMG amplitude (evaluated as a percentage) is considerable, but such a range is not uncommon in measurements of biological systems. However, it will be necessary to measure clinically affected horses to confirm the usefulness of this data set. Absolute values were variable in the healthy horses of our study, but the RA% was consistent at all 3 locations, ranging only from 48% to 85% for each horse, which makes determination of RA% a suitable comparative variable for use in the examination of clinically affected horses.29 The data reported here are intended to serve as reference values for comparison with clinically affected horses. Pathologic changes in muscle tension are likely to change the relationship between maximum and minimum EMG activity independent of the absolute values measured and, therefore, independent of muscle mass, conductivity of the skin, exact location of the electrodes, and other influences attributable to differences among horses, EMG configurations, or EMG measurement equipment. Clinically affected horses that have muscle weakness
or increased muscle tension can be expected to have reduced values for EMG activity and an altered relationship between movement and EMG activity.

References