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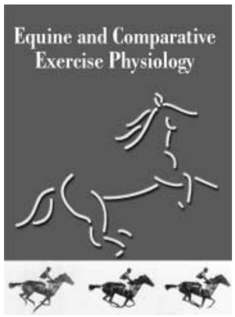

Effects of manipulative therapy on the *longissimus dorsi* in the equine back

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Research Paper

Abstract

Pain, atrophy and dysfunction of the *longissimus dorsi* in the equine back can lead to poor performance and altered biomechanics. Back problems are often treated by manipulative therapy to this muscle. The purpose of this study was to identify if manipulative therapy resulted in changes to muscle tone or electromyographic (EMG) activity immediately after treatment. We measured the muscle tone during standing using a mechanical tissue indenter and the EMG activity (both at the T16 level in the *longissimus dorsi*) during walking around a figure-of-eight course in 26 horses. The horses were randomly assigned into three groups that received: (a) spinal (McTimoney) manipulations, (b) reflex inhibition therapy or (c) a control group that was not manipulated. The muscle tone and activity were measured immediately after treatment. Both the McTimoney and the reflex inhibition groups showed significant decreases in muscle tone (*c.* 12%) and walking EMG activity (*c.* 19%). The control group showed no significant change in tone or EMG activity. These results document how the *longissimus dorsi* muscle responds immediately after manipulative therapy. Further studies would be needed to identify how long such changes persist or if such changes caused a reduction in pain or an increase in performance.

Keywords: equine; spinal manipulation; reflex inhibition; emg; muscle tone

Introduction

The equine back is central to the normal function of the musculoskeletal system and its ability to carry a rider[1]. The *longissimus dorsi* makes up part of the epaxial musculature of the equine spine. Bilateral contraction of this paraspinal muscle produces extension of the vertebral column and unilateral contraction produces lateral flexion. Horses with back pain present with rigidity of the spine, a shortened stride, reduced range of dorsoventral flexion–extension, lack of impulsion and poor performance of the horse[2,3]. When back pain is induced, by the unilateral injection of lactic acid into the *longissimus dorsi*, it primarily results in stiffness in the thoracolumbar spine and an inability to perform at fast paces[4]. Back problems accounted for 3.3% of wastage in a study of Thoroughbred racehorses[5] and are seen in horses of all breeds and in all types of work[6]; hence, effective treatment is of importance to both the welfare and the performance of horses. One common treatment option is manipulative therapy to the back. It has been argued that the main action of manipulative therapy to the back is to the spinal musculature rather than vertebral realignment directly[6,7]; however, there is little evidence to document the effects of manipulative therapies on the equine back[8–10].

In healthy animals, muscle tone is maintained through the myotatic spinal reflex and this reflex has its gain modulated by fusimotor control from the central nervous system. Manipulable spinal lesions in man can be identified by palpation of altered tissue texture that detects areas of segmental muscle overactivity or protective muscle spasms[11]. In man, spinal manipulative treatments result in consistent reflex responses[12,13] and a transient attenuation of the α-motorneuron excitability in both the cervical and the lumboacral regions[14,15]. If similar effects take place after manipulative therapy in the horse, then it is probable that the therapy will result in decreased muscle tone and activity.

Both the tone and the activity of the *longissimus dorsi* can be measured non-invasively in the horse. Muscle tone can be measured by the changes in the stiffness of the muscle and the overlying tissues, and this can be achieved using a mechanical indenter. The muscle activity can be measured using surface electromyography that records the electrical signals emitted by the muscle when it contracts. The purpose of this study was to quantify changes in the resting tone and walking activity in the *longissimus dorsi* of the horse that resulted from manipulative therapy. Two forms of therapy were investigated: spinal (McTimoney) manipulation and reflex inhibition. Spinal manipulation is a manual therapy that utilizes short-lever, high-velocity, low-amplitude-controlled thrusts across the *longissimus dorsi* towards the spinal segments and peripheral articulations[9,16]. Reflex inhibition utilizes a rapid stretch to the *longissimus dorsi* that is argued to relieve contralateral muscle activity via the myotatic reflex[17]. Both forms of therapy use manipulation of the *longissimus dorsi* to generate reflex responses within this muscle to correct imbalances in muscle activity and relieve muscle tone. We hypothesized that both forms of manipulative therapy would result in decreases in muscle tone and activity during walking in the *longissimus dorsi*, and that these decreases would not be observed in control horses that received no treatment.

Methods

We quantified the muscle tone during standing using a custom-made indenter and the muscle activity during walking around a figure-of-eight course. Measurements of tone and activity were made before and after treatment and compared with the changes in these parameters that occurred for a control group of horses that received no treatment.

Horses

In this study (height at withers: 1.62 ± 0.02 m; age 11 ± 1 years), 19 geldings and seven mares were used. The horses were general riding horses resident at the Hartpury College. They were initially seen walking and trotting in a straight line on a firm surface, by a veterinary surgeon. Exclusion criteria were overt lameness on examination; horses currently undergoing veterinary, physiotherapy, spinal manipulation or osteopathy treatments; chronic back conditions as reported by the owner or veterinarian; and those horses with a medical history of spinal pathology or ongoing foot problems. Horses were included if their owners provided signed and informed consent. An assessment by a Charted Animal Physiotherapist determined that all the horses included in the study initially had evidence of unilateral or bilateral muscle spasm along the *longissimus dorsi*, as determined by visual fasciculation on palpation, or a pain response during palpation. Each horse was randomly assigned to one of the three groups: control ($n = 9$), spinal manipulation ($n = 9$) and reflex inhibition ($n = 8$).

Procedure

Bilateral sites on the *longissimus dorsi* lateral to the T16 spinous process were identified and clipped. The muscle tone was measured at these sites and then the electromyographic (EMG) recording system attached. EMG was measured from these sites for 150 s of quiet standing in the box. The horse was then led, in hand, around a figure-of-eight course for five laps, and the EMG was measured while walking. The initial EMG and tone measurements took up to 20 min to complete. The horse was then returned to the box and received not more than half an hour of spinal manipulative therapy, half an hour of reflex inhibition therapy or half an hour of no treatment for the control group, depending on the group it had been assigned. Finally, the standing EMG and the walking EMG measurements were repeated, the EMG electrodes removed and the muscle tone retested. These final EMG and tone measurements lasted *c.* 20 min. The order of testing was kept the same for each horse.

Muscle tone

Muscle tone was measured using a custom-made tissue indenter. A 14 mm diameter nylon bead was glued to the end of a linear variable displacement transducer (LVDT; ULSC25-10, Monitran, Penn, Bucks, UK). A spring was mounted between the bead and LVDT (Fig. 1) and a metal collar (29 mm external diameter) constructed to protect these parts. The indenter was calibrated against a force transducer and digital calliper to convert its voltage output to force and displacement of the bead (displacement: $r^2 = 1.00$; force: $r^2 = 0.99$; $n = 24$).

Muscle tone was measured on a quietly standing horse that was bearing weight on all four limbs. The collar of the indenter was placed to just touch the skin surface around its perimeter. Tone within the tissue caused displacement of the bead and compression of the spring; the indenter produced a voltage output that was converted to the units, Newton m^{-1}, using the calibration constants. The tone was measured at the sites that had previously been prepared for EMG recordings (5 cm lateral to the T16 spinal processes). Tone measurements were recorded alternately from the left and the right sides and repeated 10 times.

Muscle activity

Muscle activity was measured using bipolar Ag/AgCl EMG electrodes (10 mm diameter, 22 mm spacing)

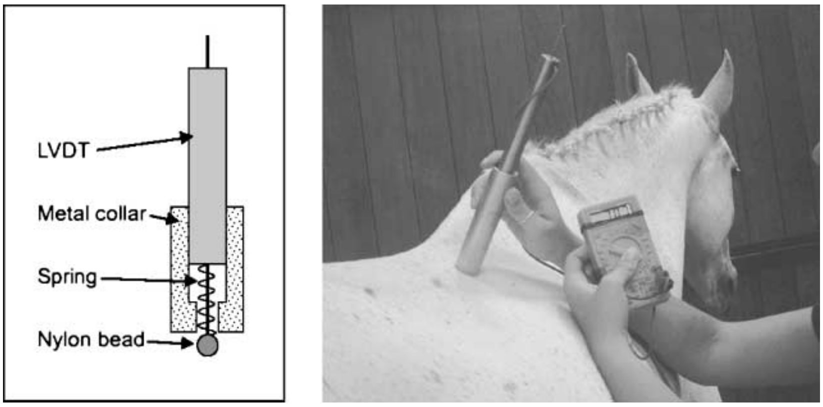

FIG. 1 The soft-tissue indenter used to quantify changes in muscle tone

adhered to the skin: prior to electrode placement, the skin was prepared by clipping, shaving and cleaning with isopropyl alcohol. Bipolar electrodes were placed overlying the *longissimus dorsi* 5 cm lateral to the T16 spinous process: prior post-mortem dissections have confirmed that this placement overlay the superficial region of the *longissimus dorsi*, clear of the *trapezius* and *gluteus medius muscles* (Christina Scheven, personal communication). A ground electrode was placed over the bony prominence of the left *tuber sacrale*. The EMG was preamplified 5000 times (Biovision, Werheim, Germany) and recorded using a 16-bit data acquisition card (6036E, National Instruments, Austin, TX, USA) in a palm-top computer attached to a surcingle (iPAQ 5550, Hewlett Packard, Bracknell, UK). The electrodes and associated cables were taped to the hair to minimize artefacts from cable movement. Data were recorded for 150 s at 1000 Hz, and were recorded for both standing and walking trials. Wherever possible the electrodes were left in place during treatments. If the electrode interfered with the treatment site then its position was marked with indelible pen and a fresh electrode replaced in the same position after treatment.

Treatments

Spinal manipulation was performed by a McTimoney Animal Practitioner in a manner routinely used by the practitioner. After an initial assessment, the treatment proceeded in a cranial–caudal direction along the back. Manipulations consisted of short-lever, high-velocity, low-amplitude-controlled thrusts across the *longissimus dorsi* and directed towards the spinal segments and peripheral articulations[16]. Treatment in the thoracolumbar region was applied to the contralateral side and directly opposite to regions of muscle spasm. If spasm was detected on repalpation then the treatment was repeated.

Reflex inhibition treatments were performed by a Chartered Animal Physiotherapist in a manner routinely used by the practitioner. The physiotherapist initially identified sites where muscle spasm was manually palpable. Throughout the cervical region, treatment was applied by applying pressure directly over the sites of muscle spasm. Treatment in the thoracolumbar region was applied to the contralateral side and directly opposite to regions of muscle spasm. At the treatment sites, pressure was applied to the skin overlying the *longissimus dorsi* using the thumb of one hand. The pressure was released immediately prior to the other hand connecting with the skin with a swift, cupped handclap. If spasm was detected on repalpation, then the treatment was repeated. The treatment proceeded in a cranial–caudal direction along the back.

The treatments for both groups lasted 20–30 min per horse. The control horses were rested, talked to and stroked in the treatment box for 30 min in a similar manner as for the treatment horses. The control horses had a handler in the box at all times.

Walking set-up

At the beginning of each test, a handler would lead each horse from its left side around the yard and identify the comfortable walking speed for that horse. The handler then set a metronome to beat at the handler's stride frequency for that walking speed. This handler's stride frequency was then used for both walking trials for the horse in order to keep the walking speed constant. Two barrels were placed 10 m apart in an indoor riding school. A line was drawn on the floor midway between the barrels. For each walking trial, the horse would start standing at the mid-line. It would then be led on a loose lead rein around the barrels at its comfortable walking pace; the loose rein avoided restriction of any neck and head movements as it walked. The horse was led in a figure-of-eight, first turning to the left and then to the right, for five complete laps. At the end of five laps, the horse would be brought to a halt at the midline. The same handler walked all the horses. An external observer timed each lap and measured the time to a front foot crossing the marked line. The total course measured 28.36 m, with a 1.25 m turning radius around the barrels.

EMG analysis

The recorded EMG signals contained a large component of interference from the electrocardiogram (ECG). The shape of the recorded ECG depends on the distance and the orientation of the EMG electrodes from the heart and was thus different at each recording site. The ECG interference was removed in the following manner. For the standing trials, the time of the heartbeats was determined by thresholding the raw EMG signal, and these times were used to segment the EMG (*c.* 100 heartbeats used per mean). The mean of these segments contains very little EMG as the EMG component is a stochastic-like signal with a zero mean. However, the mean of these segments is a good approximation to the ECG as detected by that recording electrode (Fig. 2a); this mean will be termed the ECG signal. The time of the ECG signal within the walking EMG trace was determined by cross-correlation of the two. The ECG signal was subtracted from the walking EMG at the times where it occurred[18] to leave what will be referred to as the clean EMG (Fig. 2c).

The intensity of the clean EMG was calculated using wavelet analysis[19,20], where the intensity is a close approximation of the power of the clean EMG. For each sample time, the total intensity was calculated as the sum of the intensities across wavelets 2–10 (frequency band 24–380 Hz). By filtering out the low frequencies (< 24 Hz), this process removed both movement artefacts and residual noise from the ECG. The start and end of each lap were then identified from the lap times, and the total intensity interpolated for 100 evenly spaced time windows in each lap. Each walking trial thus resulted in five estimates for the total intensity for each time window in the lap. The mean and the median of the total intensity were calculated for each time window in the lap. For statistical analysis, the EMG intensity was normalized to its mean pretreatment level for each horse. Data analysis was performed in a Mathematica programming environment (Wolfram Research Ltd. Long Hanborough, UK).

Statistics

It was hypothesized that there would be a significant decrease in muscle tone for the treatment, but not for the control groups of horses. This hypothesis was tested using one-tailed matched-pair *t*-tests. It was hypothesized that there would be a significant decrease in EMG intensity during walking for the treatment but not for the control groups of horses. This hypothesis was tested using one-tailed *t*-tests. Statistical tests were deemed significant at an $\alpha = 0.05$ level. Values are reported as mean ± standard error of sample mean (SEM).

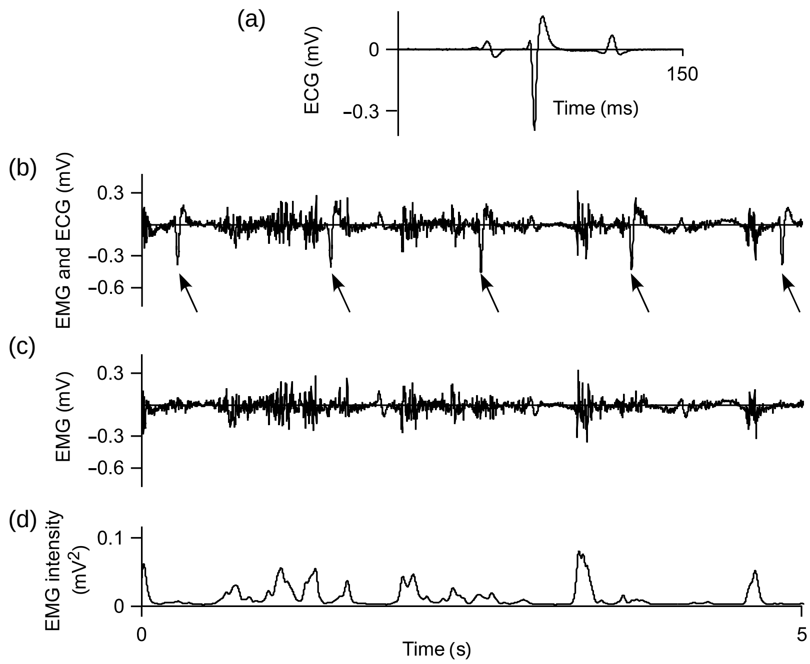

FIG. 2 EMG signals from the longissimus dorsi during walking. (a) The ECG was given by the mean raw signal from 100 heartbeats. (b) The ECG component is identified by arrows in the raw signal. (c) The clean EMG was obtained by cross-correlation and subtraction of the ECG from the raw signal. (d) The EMG intensity indicates the level of muscle activity in the longissimus dorsi

Results

The mean times for walking around each lap of the figure-of-eight course were 21.4 ± 0.2 s (an average speed of $1.3\,\mathrm{m\,s^{-1}}$). These mean walking times varied by $<1\%$ between the trials before and after treatment. The matched-pair *t*-test showed that there was no significant difference in the lap times, and thus the walking speed, between the trials before and after treatment.

Ten repeat measurements were recorded for each estimate of muscle tone; the standard deviation of these muscle tone repeats was on average 5.7% of the mean values ($n = 104$: 26 horses $\times$ 2 sides $\times$ 2 measurements per test). The significant majority of muscle sites tested showed a decrease in tone after treatment for the spinal manipulation and reflex inhibition treatment groups, but not for the control groups of horses (Fig. 3). Changes in muscle tone following treatments are shown in Fig. 4a. The muscle tone showed a significant 12.8% decrease from 601 ± 11 to $524 \pm 19\,\mathrm{N\,m^{-1}}$ after the spinal manipulation treatment ($P < 0.001$). The muscle tone showed a significant 11.6% decrease from 630 ± 12 to $557 \pm 18\,\mathrm{N\,m^{-1}}$ after the reflex inhibition treatment ($P = 0.002$). The muscle tone showed no significant decrease (0.3% increase) for the control horses following their 30-min rest period ($P = 0.853$), and the tone changed from 624 ± 17 to $626 \pm 15\,\mathrm{N\,m^{-1}}$.

The total EMG intensity was greatest on one side of the *longissimus dorsi* when the horse turned to that side. Muscle activity was four to five times greater during ipsilateral turning than for straight walking and decreased for contralateral turning (Fig. 5). Changes in the total EMG intensity following treatments are shown in Fig. 4b. The total EMG intensity showed a significant $20.7 \pm 6.9\%$ decrease after the spinal manipulation treatment ($P = 0.001$). The total EMG intensity showed a significant $17.5 \pm 4.7\%$ decrease after the reflex inhibition treatment ($P = 0.002$). The total EMG intensity showed no significant decrease ($5.7 \pm 5.0\%$) for the control horses following their 30-min rest period ($P = 0.267$).

Discussion

This study has shown that manipulative therapy to the *longissimus dorsi* results in a decrease in muscle tone and the EMG activity in this muscle during walking around a figure-of-eight course. The walking tests were setup so that the horses walked the same distance in the same time before and after treatment. Thus, the decreases in EMG activity that we observed occurred despite the mean walking velocity being kept constant. Within the walking trials we did not measure the kinematics or gait of the horses, and cannot report on whether these parameters were influenced by the treatment. Furthermore, we neither quantified the pain in the back nor investigated or quantified the mechanisms of action of manipulative therapy. Instead, we have measured functional outcomes from

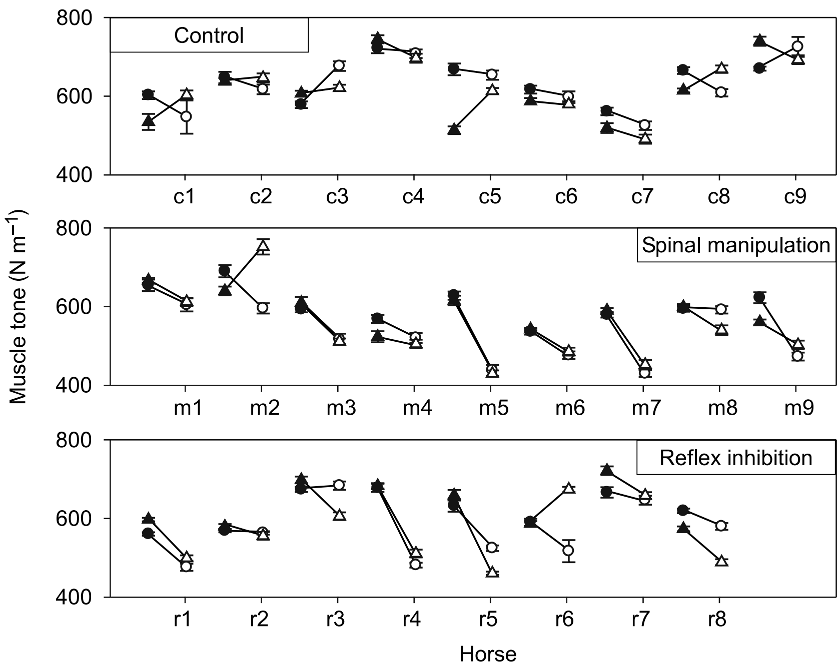

Fig. 3 Muscle tone in individual horses before and after treatment. Measurements from the longissimus dorsi on the right side are shown with triangles and from the left side with circles. Shaded symbols show measurements before treatment and open symbols after treatment. Symbols show mean $\pm$ SEM ($n = 10$ measurements)

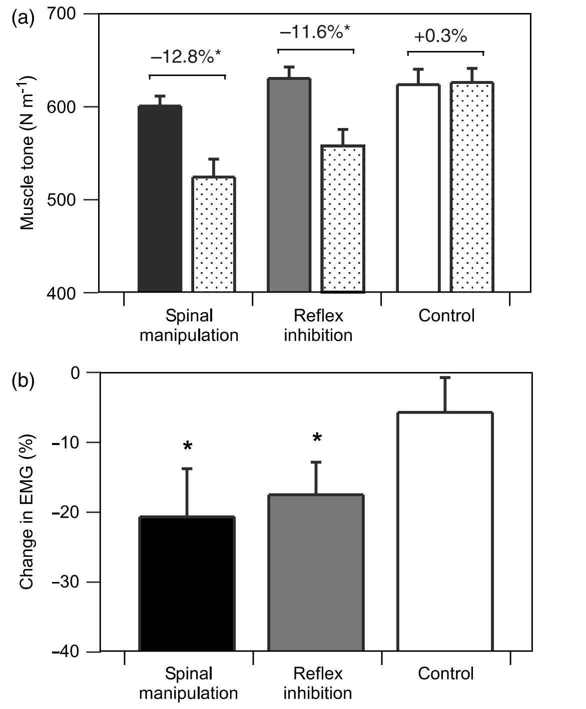

Fig. 4 Changes in muscle tone and activity in the longissimus dorsi after manipulative therapy to the back. Spinal manipulation ($n = 9$), reflex inhibition ($n = 8$) and control ($n = 9$) groups are shown by black, grey and white bars, respectively. Bars show the mean ± SEM values. Muscle tone before (solid bars) and after (stippled bars) treatment is shown in upper panel (a), and the percentage change before and after treatment is indicated. The change in EMG intensity during walking is shown in lower panel (b). Significant decreases in the values after the treatments are indicated by the asterisks for both the panels

the treatment and our conclusions reflect the measurements that we have taken.

The indenter showed that significant decreases in muscle tone occurred for both treatment groups that did not occur for the control horses. It is possible that the decreases in muscle tone after treatment were the result of suppression of α-motorneuron excitability. This type of suppression has been observed

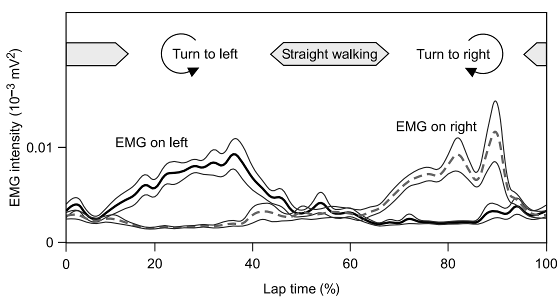

Fig. 5 The total EMG intensity during walking around the figure-of-eight circuit. The time around the circuit was normalized to the percentage lap. Mean ± SEM ($n = 9$ control horses) EMG intensity is shown for the left and the right longissimus dorsi by the solid and the dashed lines, respectively. The position along each circuit is shown by the top bar

transiently for *c.* 10–20 s post-treatment in man[15]; however, we do not know what mechanisms might make it persist for 20 min in the horse. The actual indenter readings were sensitive to a number of factors, such as the horse standing squarely on all four limbs, the head being held in a neutral position and external distractions. Care had to be taken to ensure that all these factors were controlled and the same person measured the tone for all horses. Due to these precautions, the mean standard deviation of the tone measurements across all horses was kept to 5.7 N m^{-1}. This variation was less than the 12.8 and 11.6% decreases in tone that were recorded after spinal manipulation and reflex inhibition treatments, respectively. Different automated tissue stiffness metres have been previously used in man and shown to have good intra-rater reliability and be more reliable than manual palpation[21,22]. In this study, the muscle indenter provided a useful tool for objectively quantifying changes in tone in the *longissimus dorsi* of the horse; however, it is still unclear how repeatable the absolute tone measurements would be across raters and different studies.

Surface EMG can be analysed in a number of different ways. In the previous studies of EMG in the *longissimus dorsi* of the horse, the EMG signal has been rectified and filtered using a low-pass (10 Hz) filter[23,24]. These techniques provide a smooth envelope around the EMG signal with a low time resolution. However, the low-pass filter may retain low-frequency artefacts, such as movement noise. An alternative analysis using adaptive filtering has been proposed where the filter characteristics were set to the mean period of three adjacent strides[25]. This adaptive filtering resulted in improvements in the signal to ratio, and is particularly suitable for signals with a repeatable and periodic nature, such as during walking on a treadmill. In the current study, the horses walked in an unsteady manner, starting at a quiet stand and then walking with a combination of straights and turns. Indeed, initial tests showed that the stride duration could change between straights and turns by up to 50% between adjacent strides. For this reason, it was important to use a technique that did not require the assumption of repeated gait cycles in order to analyse the EMG. The wavelet approach used in this study[19] provided a good time resolution (*c.* 20 ms: similar to the activation times of muscle twitches) and included an effective 24–380 Hz band-pass filter: this filter minimizes the contribution of low-frequency movement artefacts. Initial observations showed that the ECG formed a substantial component of the recorded signal from the *longissimus dorsi* at T16 and it was necessary to remove this artefact to result in signal purely from the *longissimus dorsi*. Different methods for removing ECG artefacts have been evaluated for surface EMG signals in man[18]. We used a cross-correlation and subtraction procedure to remove the ECG that had been determined from the recordings of the standing horses. The combination of ECG removal techniques used in this study (cross-correlation, subtraction and band-pass filtering) is similar to the best procedure identified by Drake and Callaghan[18] for maximum ECG removal with minimal EMG distortion. We recommend that similar techniques be used for recordings from the *longissimus dorsi*, particularly for slow locomotor speeds where the EMG can be relatively small compared with the ECG. The EMG analysis techniques that we have used here are suitable for standing/isometric recordings as well as steady locomotion on a treadmill and the more unsteady movements that occur during turning and over-ground gaits.

The EMG recordings showed significant decreases in muscle activity during walking for the spinal manipulation and reflex inhibition treatment groups that were not seen in the control group of horses (Fig. 4b). We do not know whether these decreases correspond to decreases in pain or increases in performance or if these decreases are clinically appropriate. Additionally, the muscles may feel sore or tender for a couple of days after treatments in man, and it is possible that the recordings made straight after the manipulative therapy in these horses would not reflect the muscle activity after a period of hours or days post-treatment. One surprising result was that the EMG intensity for the *longissimus dorsi* was five times greater during turning on the inside of the turn than for straight walking and turning to the opposite direction (Fig. 5). This result highlights the importance of the *longissimus dorsi* in providing lateral flexion for turns at a walk. For each horse, we obtained the total EMG intensity for each of five laps around the barrels. Occasionally, there were transient spikes in the EMG intensity for individual laps. It is likely that these are due to momentary increases in muscle activity due to factors such as the horse shaking and being distracted by sudden noises from outside the riding school. The mean value for the total EMG intensity shows fluctuations at these moments, whereas the median value from the five laps shows a much smoother signal. We selected the median value for further analysis as it provides representative EMG values that are not susceptible to infrequent random disturbances. The results from this analysis showed significant decreases in EMG intensity following the treatments. It should be noted that these decreases would disproportionately reflect decreases in EMG intensity during turning as this is the time when the EMG intensity was greatest.

The results from this study show that both spinal manipulation and reflex inhibition therapy to the equine back result in decreased resting tone of the *longissimus dorsi* and decreased activity of this muscle during walking. It should be noted that this study neither provides any evidence for the mechanisms that are behind these changes nor indicates that treatment outcomes include a reduction in pain or an increase in performance. Furthermore, the study identified differences in tone and muscle activity that occurred immediately after treatment, but does not quantify how long such changes persist. However, this study does provide evidence to support the clinical observations that these treatments result in a reduction in palpable muscle tone and an alteration in muscle activity during walking.

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