SURFACE ELECTROMYOGRAPHY OF ABDOMINAL AND SPINAL MUSCLES IN ADULT HORSERIDERS DURING RISING TROT

Annette Pantall , Sharron Barton and Peter Collins

European School of Osteopathy, Maidstone, UK

The purpose of this study was to determine activation patterns of iliocostalis lumborum and rectus abdominis in horse riders during rising trot. Horse riders (n=10) of varying abilities (casual rider to Prix St George rider), aged from 20 – 57 were involved in the study. Electromyographic activity was recorded bilaterally from iliocostalis lumborum and rectus abdominis. In addition, movement at the lumbosacral joint was recorded using an electrogoniometer. The subjects were asked to walk and then perform rising trot on their horses. The electromyographic signals were full-wave rectifed and a moving filter was applied to the signal. Patterns of activation between sides and between muscles were determined. Coactivation of the right and left sides was present for all riders. The novice riders displayed coactivation of rectus abdominis and iliocostalis lumborum whereas the experienced riders had a phase shift between these two muscles. Rectus abdominis behaved as an agonist in the experienced rider, contracting as the rider made contact with the saddle on the outside diagonal. Controlled activation of the rectus abdominis is an important feature in the experienced rider. Training regimes for horse riders should incorporate specific exercising of the abdominal muscles.

KEY WORDS: horseback riding, electromyography, abdominal muscle, spine

INTRODUCTION: Horseback riding is a unique sporting activity in that it involves two living entities moving together in a synergistic fashion to produce a coordinated movement pattern. The movement of the horse is transmitted to the rider principally through forces acting on the saddle. In turn, the position of centre of mass of the rider's trunk relative to the horse will influence the gait of the horse. The position of the centre of mass of the rider's trunk is controlled mainly by contractions of the abdominal muscles and paravertebral muscles. Knowledge about the kinetics and kinematics of the rider is important for equestrian sports, in particular dressage. Dressage demands very precise sequencing of the horse's footfall, which implies equally even movement of the rider's trunk (Hodson et al., 1999). The type and frequency of movement of the rider will depend on the gait of the horse. A variety of gaits have been described, which include walk, tölt, pace, passage, trot, canter, rotary gallop and transverse gallop (Barrey, 1999). Trot is a two-time movement with the forelimb and contra-lateral hindlimb moving together. A full gait cycle during trot is composed of two stance phases and two swing phases. In rising trot, the rider will be seated during one of the stance phases and out of the saddle for the second stance phase. Rising trot requires the rider to control trunk movement accurately in order to minimize variability of the kinematics of the horse. Movement of the trunk is initiated primarily by contraction of the abdominal and paravertebral muscles. Surface electromyography (sEMG) provides a non-invasive method to analyze the activity of these muscles. However, few biomechanical studies have been undertaken on the horserider. The two main investigations on sEMG activity of riders' muscles have been performed by Terada (2000) and Terada et al. (2004). The former study reported a difference in muscle activation patterns between novice riders and advanced riders during walk, trot and canter. The advanced riders displayed cocontraction of rectus abdominis (RA) and the erector spinae and minimal involvement of adductor magnus. The study by Terada et al. (2004) investigated timings of muscle contraction of upper extremity muscles and RA in advanced riders during sitting trot. The purpose of this study was to investigate the contraction pattern of two trunk muscles to establish how the rider changes trunk position and whether the pattern differs between novice and advanced riders.

METHODS: Data Collection: Ten horse riders participated in the study. The age of the rider varied as did the height of the horse (Table 1). The riders were of mixed ability ranging from novice riders to experienced riders competing at international (Prix St. George) level. The sEMG of four trunk muscles was measured. The right and left RA and the right and left iliocostalis lumborum (IL) were selected for measuring. IL is the most lateral muscle of the erector spinae and therefore is a significant lateral flexor of the trunk. The Biometrics DataLOG (Biometrics Ltd, Gwent, UK) with sx232 bipolar electrodes was used to record the sEMG. The electrodes contained a high pass 3rd order filter, cut-off 25Hz, and a low pass 8th order filter, cut-off at 460 Hz. The DataLOG was attached to the rider's waist via a belt. The site of electrode placement was in the position recommended by the SENIAM report (Freriks & Hermens, 1999) for IL and by Cram and Kasman (1998) for RA. The skin area was cleaned with an alcohol wipe prior to attaching the electrodes. Sampling of sEMG was at 1000Hz in accordance with the Nyquist Theorem. Movement of the lumbar spine was measured in the sagittal and coronal planes using a twin axis goniometer (Biometrics Ltd, Gwent,UK). One end of the goniometer was fixed with surgical tape to the skin overlying the middle of the sacrum and the other end was attached to skin overlying the spinous process of the fifth lumbar vertebra. Data from the goniometer was collected at a sampling rate of 20Hz. All measurements took place in an indoor school at a livery stable in Kent. Riders were asked to initially sit still for 60 seconds then to perform a medium walk between 2 markers placed 18m apart and finally to do a working rising trot between these 2 markers. All riders rode in the anti-clockwise direction and sat down on the outside diagonal (right forelimb and left hindlimb in contact with the ground).

Table 1 Age, height, weight of rider, experience of riding and height of horse.

Subject	Age (years)	Height (m)	Weight (kg)	Number of years riding	Height of horse (m)
S1	42	1.65	76.4	15+	1.73
S2	47	1.68	73.2	15+	1.65
S3	23	1.68	58.5	15+	1.52
S4	28	1.79	63.6	10-15	1.68
S5	47	1.88	82.7	1-5	1.50
S6	36	1.57	57.0	15+	1.47
S7	20	1.60	58.2	10-15	1.52
S8	22	1.70	66.8	15+	1.50
S9	57	1.70	76.4	1-5	1.65
S10	43	1.62	54.1	1-5	1.57

Data Analysis: Analysis of the raw sEMG consisted first of full wave rectification of the signal and subsequent filtering of the data. Smoothing of the data was undertaken using the MATLAB (The Mathworks Inc., Natick, Mass.) forward / reverse *filtfilt* routine with a 100ms window to create a linear envelope. A 10-second mid-section of the filtered data was taken for each of the muscles during halt, walk and trot and the mean values calculated. Statistical tests were then applied to determine whether there was a change in mean value of the sEMG and lumbosacral angles from halt to walk, walk to trot and halt to trot. Fisher's F-test was applied to the data to determine whether there was equal variance and then the appropriate t-test was applied. The patterns of sEMG activity were observed to determine the presence of coactivation between RA and IL and the relationship of the sEMG to the lumbosacral angle in the sagittal plane.

RESULTS: Full sEMG and kinematic data were obtained for 7 out of the 10 subjects. No left RA data was available for subject S2, no right RA data for subjects S2 and S4 and no left IL was recorded from subject S1. There was increased activity of all muscles from halt to trot and increased activity of IL from walk to trot. The mean sagittal lumbosacral angle was greater from halt to trot but was less during trot than during walk. The lumbosacral angle showed a regular pattern of flexion and extension during riding trot for the 7 experienced riders with a frequency of 1.29 Hz to 1.88 Hz. A small amount of extension of the lumbosacral junction was observed as the rider's pelvis made contact with the saddle (Figure 1).

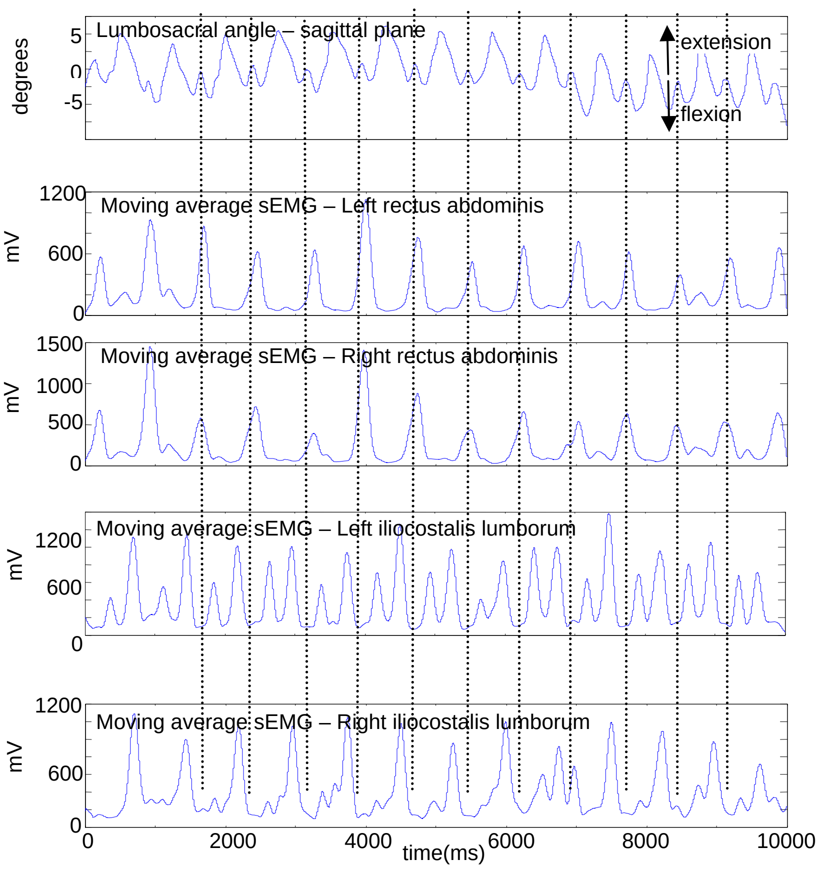

Figure 1: sEMG and L/S angles in rising trot for Subject S8. Dotted lines indicate times when contact is made with the saddle.

RA displayed peaks of activity at maximum lumbosacral flexion for 5 of the riders (S1, S3, S6, S8 and S10) and in one case maximum activity at extension (S4). In the remaining 4 cases, there was no clear correlation between lumbosacral angle and RA activity. There was a less obvious pattern for IL with 3 subjects (S8, S9 and S4) showing greatest activity at lumbosacral flexion and 2 subjects (S3 and S6) exhibiting peak activity at extension. All subjects displayed evidence of synergistic muscle activity between the left and right sides. Patterns of coactivation between RA and IL varied between riders. Four of the subjects (S2, S7, S9 and S10) displayed synergistic contraction of RA and IL whereas another group of 4 riders (S3, S4, S6 and S8) showed a phase shift in activity between RA and IL. Subjects S1 and S5 demonstrated irregular patterns of activity between RA and IL.

DISCUSSION: One would anticipate the frequency of the horserider's trunk movements to be similar to the frequency of the horse's footfall during rising trot. However, the frequency range of the lumbosacral angle in the sagittal plane was smaller than the frequency of working trot that has been calculated to be from 1.39 Hz to 1.56 Hz (Morales et al., 1998). This difference can be attributed to the varying abilities of the riders and sizes of the horses. Since all the riders were riding in the anti-clockwise direction, peak height from the saddle was reached during mid-stance of the inside diagonal. The lumbosacral angle will be at maximum extension during this phase of the horse's gait. During terminal stance of the inside diagonal, the rider descends relative to the saddle to sit during the outside diagonal. The lumbosacral angle is at maximum flexion during midstance of the outside diagonal. In the experienced riders, RA behaved as an agonist and was most active during lumbosacral flexion. This finding is consistent with that of Terada (2000) who reported that RA was maximal during mid-stance although this was measured during sitting trot.

The riders showed different patterns of activity for RA and IL. The phase-shifted pattern of activity of RA and IL activity was only evident in the more experienced riders whereas coactivation of muscles was observed in the less experienced riders (S9 and S10) and rider S2 who had undergone spinal surgery. An additional observation was that subjects S2 and S9 were two of the oldest riders. Coactivation of muscles has been associated with the ageing process (Enoka et al., 2003). Coactivation of muscles requires that the agonist must contract more strongly to overcome the force developed in the antagonist muscle. This pattern of muscle activity is therefore an energetically inefficient control system. The least experienced rider, subject S5, displayed a very varied pattern of sEMG activity and irregular changes in lumbosacral angle suggesting poor development of neuromuscular control.

CONCLUSION: Analysis of sEMG provided information regarding the ability of the horserider to adjust the position of their trunk and through this affect the movement of the horse. The more experienced rider used their RA as an agonist to the dominant movement of trunk flexion. This indicates more efficient control of muscle activation than in novice riders. Inexperienced riders coactivated their RA and IL, which utilizes a greater amount of energy. The study indicated that age may be an additional factor affecting the control strategy of the trunk muscles, with older riders less able to activate selectively their RA without IL contraction to produce trunk flexion. Further research is needed to investigate the relationship between the rider's control of muscle activity and how it is reflected in the horse's performance.

REFERENCES:

Barrey, E. (1999). Methods, Applications and Limitations of Gait Analysis in Horses. *The Veterinary Journal*, *157*, 7-22.

Cram, J. & Kasman, G. (1998). *Introduction to surface electromyography*. Maryland: Aspen Publishers.

Enoka, R.M., Christou, E.A., Hunter, S.K., Kornatz, K.W., Semmler, J.G., Taylor, A.M. & Tracy, B.L. (2003). Mechanisms that contribute to differences in motor performance between young and old adults. *Journal of Electromyography and Kinesiology*, *13*(1), 1-12.

Freriks, B. & Hermens, H.J. (1999). *European Recommendations for Surface Electromyography-SENIAM Project*, Enschede: Roessingh Research and Development.

Hodson, E.F., Clayton, H.M. & Lanovaz, J.L. (1999). Temporal analysis of walk movements in the Grand Prix dressage test at the 1996 Olympic Games. *Applied Animal Behaviour Science*, *62*, 89-97.

Morales, J.L., Manchado, M., Cano, M.R., Miro, F. & Galisteo, A.M. (1998). Temporal and linear kinematics in elite and riding horses at the trot. *Journal of Equine Veterinary Science*, *18*, 835-839.

Terada, K. (2000). Comparison of Head Movement and EMG Activity of Muscles between Advanced and Novice Horseback Riders at Different Gaits. *Journal of Equine Veterinary Science*, *11*, 83-90.

Terada, K., Mullineaux, D.R., Lanovaz, J., Kato, K. & Clayton, J.M. (2004). Electromyographic analysis of the rider's muscles at trot. *Equine and Comparative Exercise Physiology*, *I*, 193-198.