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Descriptive electromyography signals analysis of equine longissimus dorsi, rectus abdominis and gluteus medius muscles during maneuvers used to activate the core

[*Análise descritiva do sinal eletromiográfico dos músculos longuíssimo dorsal, reto abdominal e glúteo médio de equinos durante a realização de manobras utilizadas para ativação do core*]

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ABSTRACT

Maneuvers to activate the equine's core can make a difference in their physical and psychic health. Although these activities are recommended and practiced, there is little research proving their effectiveness. This article aims to describe, through surface electromyography, the occurrences, durations and sequences activity of longissimus dorsi, rectus abdominis and gluteus medius during thoracolumbar flexion (TLF), lumbar and lumbosacral flexion (LLSF), global flexion (GF), which is the combination of TLF and LLSF, and tail traction (TT). Seven healthy adult horses of three different breeds performed five repetitions of these movements for five seconds (sec). Electromyographic activity was captured with non-invasive superficial sensors positioned in the skin regions covering these muscles. The sequence was performed once per animal, muscle activity captured by surface electromyography, data from two replicates of each animal were selected, analyzed on matLab software and data tabulation were described during each maneuver. These maneuvers provoked punctual and transient activation of muscles mentioned above, confirming the ability to activate equine core muscles. However, responses were not standardized, which means there were variations of occurrence, duration and sequence, suggesting that for practical application of those maneuvers it is necessary to perform more repetitions with longer durations to activate more muscles.

Keywords: EMG, equine pilates, flexibility, stability, warming-up

RESUMO

Manobras para ativação da musculatura do core equino podem ser diferenciais para saúde física e psíquica dos animais, sendo recomendadas e praticadas, mas existem poucas pesquisas comprovando a eficácia delas. Este artigo tem como objetivo descrever, por meio da eletromiografia de superfície, as ocorrências, as durações e as sequências temporais da atividade muscular do longuíssimo dorsal, do reto abdominal e do glúteo médio durante a realização das manobras de flexão toracolombar, flexão lombar e lombossacra, flexão global (toracolombar e lombossacra) e tração de cauda. Para isso, sete equinos adultos e hígidos de três raças realizaram esses quatro movimentos clássicos para ativar o core equino, com cinco repetições e manutenção do estímulo reflexivo por cinco segundos. Durante a realização, a atividade eletromiográfica foi capturada com a utilização de sensores superficiais posicionados de forma não invasiva em regiões cutâneas referentes a cada músculo. O protocolo completo de manobras foi realizado uma vez por cada animal enquanto a atividade muscular era capturada. Posteriormente, duas repetições de cada animal foram triadas e submetidas ao software *matLab para análise. Com base na tabulação dos dados, foram descritas as variáveis eletromiográficas de presença ou ausência de ativação muscular, a duração média dos picos eletromiográficos superiores ao RMS (*root mean square*) e a sequência da atividade muscular observada durante cada manobra. Essas manobras provocaram ativações pontuais e transitórias nos três músculos, o que confirma a capacidade de excitar músculos do core equino.*

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Contudo, as respostas não foram padronizadas, sugerindo que, na prática dessa atividade, devem-se realizar mais repetições com durações superiores a cinco segundos, a fim de se buscarem maiores ativações.

Palavras-chave: EMG, estabilidade, flexibilidade, pilates equino, pré-aquecimento

INTRODUCTION

Currently the interest in equine rehabilitation is growing and it seeks the prevention, recovery or improvement of athletic performance. However, although there is great potential, relatively few scientific researches were developed to elucidate how different approaches to activate the equine's core can have an influence in proprioception, flexibility and strength of the horses. Because of that, recommendations are usually made empirically and based on human physiotherapy (Kaneps, 2016; Williams and Mckenna, 2016). Regular practice of some movements is advised to increase or maintain flexibility, stability and strength of core muscles, because it activates and rebalance the epaxial and hypaxial muscles of the vertebral column, which are essential for good posture at rest and movement, avoiding new lesions and recurrences (Higgins, 2011).

Equine core muscles have an influence on their well-being and athletic performance. Longissimus dorsi (LD) has an influence in flexibility and stability of cervical and thoracolumbar sections. Pain in these muscles may cause reluctance to protract and retract hind limbs. Rectus abdominis (RA) also plays a role on the desired protraction during equitation, because it acts flexing the thoracolumbar spine. Dysfunction of gluteus medius (GM)may cause reduction of steps and make lateral movements or changes in directions harder. It happens because it is the main extensor muscle of the lumbosacral joint and contributes to abduction and flexion of hind limbs (Williams and Mckenna, 2016; Zsoldos *et al*., 2018).

Surface electromyography (EMG) has been used for sports related research and rehabilitation in humans (Vigotsky *et al*., 2018). In animals, despite the main difficulty is standardize EMG signals through maximum voluntary isometric contractions (MVIC), researches increased, mainly with equines (Valentin and Zsoldos, 2016). Because it is a non-invasive technique without wire, surface wireless EMG allows measuring muscular activity, analyses of synergic, and antagonist reactions during movements (Zsoldos *et al*., 2014). This article's goal is to describe using surface EMG the occurrence, mean duration and sequence of excitatory activity from LD, RA and GM during the stimulations of four maneuvers that probably activates the equine core.

MATERIAL AND METHODS

Experimental outline to this research was submitted to the Etic Commission of Animal Use – CEUA/UFV that certified process number 02/2018 which is coordinated by professor Brunna Patrícia de Almeida da Fonseca of Veterinary Department. It is accordantly with valid legislation (law number 11.794 of 08 of October of 2008), Normative Resolutions edited by CONCEA/MCTI, DBCA (Brazilian Guidelines of Practice for Care and Use of Animals to Scientific and Didactic Ends) and Guidelines of Practice of Euthanasia recommended by CONCEA/MCTI, approved in 15 of June of 2018 with validity of 12months. To collect data seven healthy adult horses were used.

From these, four were Mangalarga Marchador breed, two Pure Blood Lusitano and one Quarter Horse, this last was the only female of the group. These horses were between 8 and 14 years old (11+/- 2 years), weight varying between 380 and 480kg (439 +/- 40Kg), minimum withers height of 1.43m and maximum of 1.60m (1.52 +/- 0.06cm), all from an equestrian training center in Zona da Mata Mineira region, where they were exposed to the same daily and level of exercise. Muscles LD, RA and GM were located by palpating anatomic references, based on the equine research of Simonato (2016) and human recommendations of project Surface Electromyography for Noninvasive Assessment of muscles (SENIAM).

After localizing the cutaneous area of each muscle, hair was clipped using liquid soap and blades. This was to make it easier to glue hold surface EMG sensors (Wearable sensors for movement sciences - Delsys® – USA) by using hypoallergenic double-sided tape into the horse's skin. Muscle activation data was obtained by a wireless EMG system Trigno®, with sixteen channels, maximum frequency acquisition of

2000 Hz and EMGworks® software. The EMG sensors were attached bilaterally in the same direction of muscle fibers and with references cranially. For LD, sensors were attached using as reference the distance of five centimeters laterally from the middle on each side of the eighteenth thoracic vertebrae. For RA, the distance was six centimeters bilaterally from the umbilical scar. For GM, it was considered a mean distance between hip joint and spinous process of second sacral vertebrae from both sides. When data was collected, EMG signals captured were categorized visually as good, acceptable, noisy or bad.

Then two best repetitions of each movement were put into matLab, meaning, trials where the animal didn't make undesirable movements and the largest number of sensors were good or acceptable. In matLab software, signals were submitted to a Butterworth of fifth order type bandpass filtered at 10-500 Hz, based on Simonato (2016), to eliminate or reduce interferences by attenuating to zero frequencies lower than 10Hz or higher than 500 Hz. EMG signal was also processed by root mean square (RMS) formula quantifying signal and calculating RMS mean. RMS makes it possible to compare activation of each muscle with them, since it's not possible to use mVIC with irrational animals. From RMS, graphs were categorized and arranged in tables as active (1) or inactive (0) according to temporal domain analysis of each gather.

Graphs that presented increased amplitude in microvolts (µV) higher than the mean of RMS were considered active (1). Initial and ending times of one or more peaks were also arranged in tables for analysis and description. Descriptive analysis was made from variables of active or inactive, duration of mean EMG peaks and sequence of muscle activity observed, being these data were organized into tables and categorized by movement, muscle, animal and repetition. Active or inactive findings were compared with the expected and quantified in percentage (%) by dividing expected activity quantity observed by 14, which was the total number of repetitions made by the seven horses in each movement.
Total start and end times of each EMG peak were organized into a table and subtracted to find total duration of each repetition, which was then divided by the number of EMG peaks observed during each movement to find total mean duration. Sequences of activation in each repetition were found considering the beginning and ending times of each EMG peak. Start times were categorized in crescent order and their respective muscles put into a table at the same order for analysis. If any muscles presented distinct peaks during execution time in the same movement, these were registered separately making it possible to observe repetition of muscles on the table. The equine's core activation maneuvers were made on a training center on a firm and not slippery ground. EMG data gathering of each maneuver for the equine's core activation, was started and finished with half a second of neutral position by contact to the head collar.

Reflexive stimuli were kept for five seconds followed by an interval of at least one minute between repetitions, trying to avoid any muscle warm up effect or fatigue. Movements were executed in sequence, in the following order: thoracolumbar flexion (TLF), lumbar and lumbosacral flexion (LLSF), global flexion (GF), which is the combination of TLF and LLSF, and tail traction (TT). These protocols were chosen for their typical reflexive stimuli prescribed to activate the equine's core. TLF was made with rhythmic digital stimulus in the middle line of xiphoid cartilage of sternum bone, the aim was to provide a ventroflexion, mainly on the thoracic segment, creating a soft elevation of dorsum (Figure 1A and B). LLSF was induced by repetitive bilateral digital stimulus in the base of the tail at ischial tuberosity height to make flexion of lumbar sacral joint with hip joint extension and back elevation (Figure 2A and B).

GF was induced by simultaneous combination of digital stimuli at xiphoid cartilage and base of the tail, aiming to produce a bigger ventroflexion of the thoracolumbar segment and flexion of the lumber sacral joint with hip joint extension (Figure 3A and B). TT was made by a gentle and gradual traction in caudoventral direction, applied with the instructor's weight to stimulate the equine to bring his center of mass cranially as a response to the imbalance created (Figure 4).

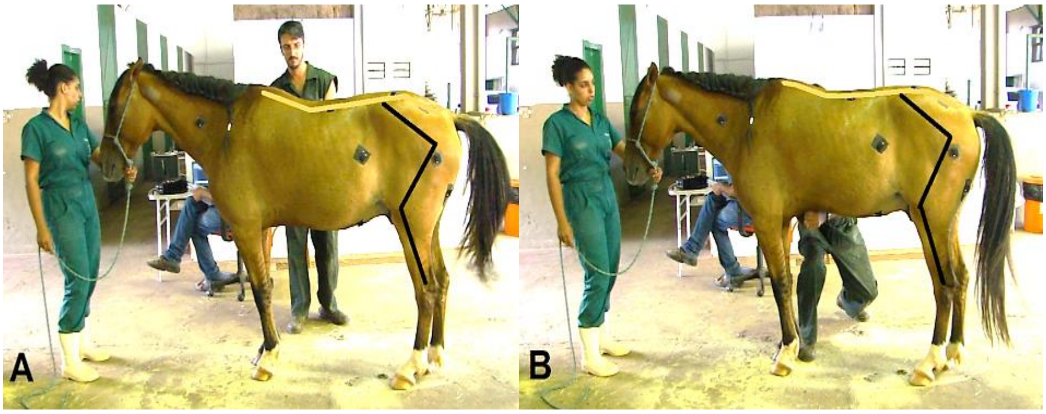

Figure 1A e B. Equine movement with emphasis to thoracic, lumbar and sacral segments of vertebrae column (orange line) and hip and knee joint (black line) in initial position (A) and during thoracolumbar flexion induced by digital stimulus in middle line of xiphoid cartilage of sternum (B). Source: Personal file.

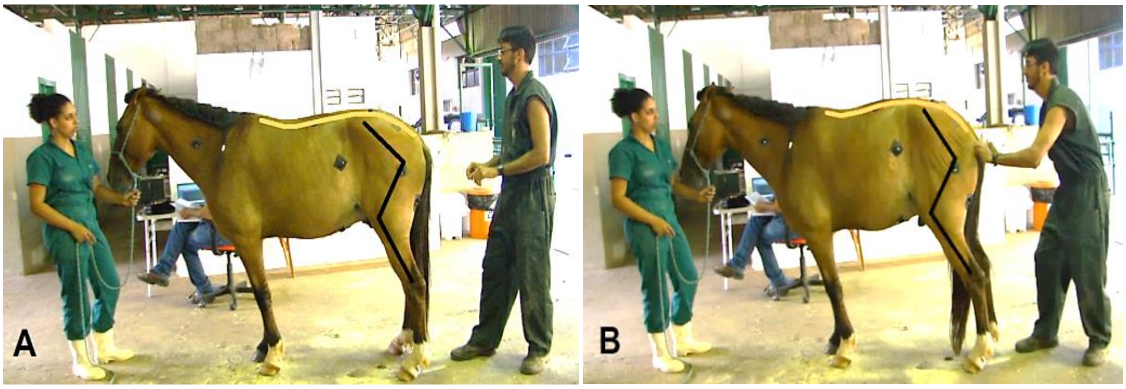

Figure 2A e B. Equine movement with emphasis to thoracic, lumbar and sacral segments of vertebrae column (orange line); hip and knee joints (black line) in initial position (A) and flexion of lumber sacral joint and back elevation induced by repetitive bilateral digital stimulus in base of the tail at ischial tuberosity height during lumbar and lumbosacral flexion (B). Source: personal file.

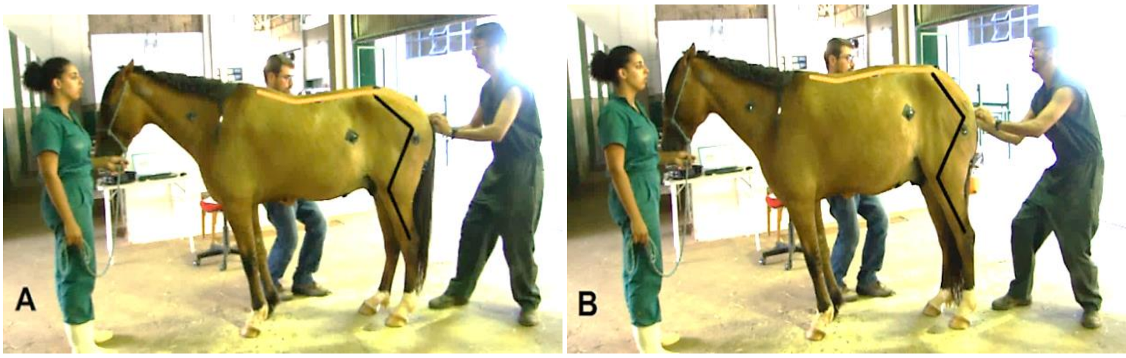

Figure 3A e B. Equine movement with emphasis to thoracic, lumbar and sacral segments of vertebrae column (orange line) and hip and knee joints (black line) in initial position (A). And at ventroflexion of thoracolumbar segment and flexion of lumber sacral joint with hip joint extension induced by simultaneous combination of digital stimuli at xiphoid cartilage of sternum and bilaterally near to ischial tuberosity at base of the tail during global flexion (B). Source: Personal file.

Figure 4. Equine response with emphasis to thoracic, lumbar and sacral segments of vertebrae column (orange line) and hip and knee joints (black line) during gentle and gradual traction applied with weight of the instructor caudoventrally to produce a shift in center of the equine mass at tail traction movement. Source: Personal file.

RESULTS AND DISCUSSION

TLF aims to induce ventroflexion, especially at the thoracic segment with elevation of the back (Figure 2A and B). It was expected a concentric bilateral contraction of RA, which was present in 100% of repetitions with higher mean durations, totalizing 1.19 and 1.42 second (sec) in left (L) and right (R) antimeres, respectively. An unexpected increase in EMG signal amplitude in 79% of repetitions was observed from LD and GM. But mean durations of 0.79, 0.60, 0.76 and 0.69 sec in L and R antimeres were smaller than RA (Table 1). There is a tendency in the activity sequence when it begins with RA, followed by LD and GM, but some repetitions showed reactivation throughout data gathering time (Table 2). At LLSF it was expected flexion of the lumbosacral joint with hip joint extension and elevation of the back (Figure 3A and B) made by bilateral concentric contraction of RA and GM with activation in 100% of repetitions. Mean durations were 2.23, 2.34, 2.54 and 2.79 sec in L and R antimeres respectively. However, in LLSF it was also observed a non-expected EMG activation of LD in 64% and 50% of repetitions with mean duration of 0.75 and 0.63 sec in L and R antimeres respectively (Table 3). There was a tendency following activation to be GM, RA and LD but in some repetitions, they were reactivated (Table 4).

Table 1. muscle activity during thoracolumbar flexion of each horse (1 to 7) in repetitions (A and B). Compared by the expected percentage (%), mean and standard deviation (SD), in seconds, between the mean duration (total duration divided by the number of activations) of repetitions (A and B) for each horse in each muscle and total. Where: LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis); RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius); O (active); X (inactive); % (expected observed quantity/ 14)

Thoracolumbar flexion (sternum digital stimulus)																	
Horse		1		2		3		4		5		6		7		Expected	%
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	Mean ± SD (total)	
Muscles	**LLD**	O	O	O	O	O	O	O	O	X	X	O	O	O	X	**X**	21
	Mean ± SD	0.87±0.21		2.17±2.26		0.34±0.08		0.66±0.13		0.00±0.00		1.16±0.57		0.37±0.52		**0.79±0.96**	
	RLD	O	O	O	O	O	O	O	O	X	X	O	O	O	X	**X**	21
	Mean ± SD	0.76±0.00		0.61±0.01		0.42±0.30		0.76±0.26		0.00±0.00		0.81±0.54		0.85±1.20		**0.60±0.48**	
	LRA	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean ± SD	0.68±0.20		0.78±0.01		0.90±0.71		2.57±1.73		0.85±0.22		0.49±0.06		2.11±0.66		**1.19±0.95**	
	RRA	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean ± SD	0.98±0.31		1.42±0.54		0.68±0.25		3.30±0.50		0.50±0.00		1.25±0.08		1.79±0.93		**1.42±0.97**	
	LGM	O	O	O	O	O	O	X	O	X	O	O	X	O	O	**X**	21
	Mean ± SD	0.50±0.00		1.72±0.11		0.67±0.19		0.31±0.44		0.12±0.17		0.16±0.23		1.83±0.80		**0.76±0.74**	
	RGM	O	O	O	O	O	O	O	O	X	X	O	O	O	X	**X**	21
	Mean± SD	0.57±0.35		1.23±1.29		0.70±0.28		0.96±0.28		0.00±0.00		0.75±0.62		0.63±0.89		**0.69±0.61**	

Table 2. Muscle activation sequence during thoracolumbar flexion of each horse (1 to 7) in repetitions (A and B). Where LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis); RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius)

Thoracolumbar flexion (sternum digital stimulus)																	
Horse		1		2		3		4		5		6		7			
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	Predominantly	
Sequence	1°	RRA	RRA	LLD	LGM	RRA	LLD	LRA	LGM	RRA	LRA	LRA	LRA	RRA	RRA	RRA	
	2°	RRA	RLD	RLD	RRA	LRA	LGM	RRA	RRA	LRA	RRA	LRA	RRA	RLD	LGM	RRA	
	3°	LGM	LRA	LGM	LGM	RRA	RRA	LGM	LGM		LGM	LLD	LRA	LRA	LRA	LRA	
	4°	LRA	RRA	LRA	LGM	LLD	RLD	LLD	LLD			RLD	LLD	LGM		LLD	
	5°	LLD	LLD	LGM	RRA	RLD	LRA	RLD	LRA			RRA	RLD	LGM		RLD	
	6°	RLD	RLD	LGM	RLD	LGM	LGM		LGM			RLD	LGM	LLD		RLD	
	7°	RRA	LGM	RLD	LRA	LGM	LGM		LLD			LGM				LGM	
	8°	LGM	LLD	RRA	LRA		RRA		LGM			LGM				RRA	LGM
	9°		LRA	LRA	LLD		LRA		RLD			LLD				LRA	
	10°		LGM	RRA	LGM		RLD		LRA			RLD				RLD	LGM
	11°		LGM	RLD	RLD		LGM									RLD	
	12°			LRA	LRA		LLD									LRA	
	13°				RRA		LRA									LRA	RRA
	14°				LGM		LGM									LGM	LGM

Table 3. Muscle activity during lumbar and lumbosacral flexion of each horse (1 to 7) in repetitions (A and B). Compared by the expected percentage (%), mean and standard deviation (SD), in seconds, between mean duration (total duration divided by number of activations) of repetitions (A and B) for each horse in each muscle and total. Where: LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis); RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius); O (active); X (inactive); % (expected observed quantity/ 14)

Lumbar and lumbosacral flexion (digital stimulus at the ischiatic tuberosity)																	
Horse		1		2		3		4		5		6		7		Expected	%
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	Mean±SD (total)	
Muscles	**LLD**	X	O	X	X	X	O	O	O	O	O	O	O	X	O	**X**	36
	Mean±SD	0.35±0.49		0.00±0.00		0.50±0.71		1.52±0.86		0.88±0.08		1.82±0.71		0.22±0.31		**0.75±0.77**	
	RLD	X	X	X	X	O	X	O	O	O	O	O	O	X	X	**X**	50
	Mean±SD	0.00±0.00		0.00±0.00		0.25±0.35		1.49±0.28		0.84±0.29		1.84±0.69		0.00±0.00		**0.63±0.78**	
	LRA	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	1.71±1.30		3.09±2.00		1.30±0.35		2.52±0.37		2.08±1.15		1.99±0.55		3.07±0.10		**2.25±1.00**	
	RRA	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	1.85±0.57		2.55±2.59		1.32±0.12		3.13±1.06		1.36±0.13		1.87±0.73		4.32±0.62		**2.34±1.34**	
	LGM	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	3.39±1.97		4.85±0.93		1.23±0.04		1.10±0.05		2.22±0.69		2.19±0.31		2.79±0.94		**2.54±1.43**	
	RGM	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	1.84±0.68		3.68±1.79		1.00±0.57		3.99±3.13		2.64±2.48		3.04±2.10		3.33±0.09		**2.79±1.70**	

Table 4. Muscle activation sequence during lumbar and lumbosacral flexion of each horse (1 to 7) in repetitions (A and B). Where LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis); RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius)

Lumbar and lumbosacral flexion (digital stimulus at the ischiatic tuberosity)																	
Horse		1		2		3		4		5		6		7			
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	Predominantly	
Sequence	1°	LGM	RGM	RGM	LGM	LRA	RGM	RGM	RGM	RRA	LRA	RGM	LRA	RRA	RRA	RGM	
	2°	RRA	LGM	RRA	RGM	RRA	LRA	RRA	RRA	LLD	RRA	LGM	RLD	LGM	RGM	RRA	
	3°	RGM	LRA	LRA	LRA	RRA	RRA	LRA	LGM	RLD	RLD	LLD	RGM	RGM	LRA	LRA	
	4°	LRA	RRA	LGM	RGM	RRA	LGM	LLD	LRA	RLD	LGM	LRA	LLD	LRA	LGM	LRA	LGM
	5°	LGM	LLD		LRA	RGM	LLD	RLD	LGM	LRA	RGM	RGM	RRA		LLD	LLD	RGM
	6°	RGM	RGM		RRA	LRA	RRA	LGM	LLD	LLD	RRA	LGM	LGM			RRA	LGM
	7°		RGM		LRA	RGM	RGM	LGM	RGM	LGM	LLD	RLD	LGM			RGM	
	8°		LRA		RRA	LGM	LGM	LRA	LRA	RGM	LGM	RRA	RLD			LRA	LGM
	9°					RLD	LRA	RRA	RLD	RRA	RGM		LLD			RLD	RRA
	10°						RRA	LLD	RGM	RGM	LRA		RRA			RRA	RGM
	11°							RLD		RRA	RLD		LRA			RLD	

At GF it was expected to create a ventroflexion of most parts of the thoracolumbar segment and lumbar sacral joint with hip joint extension (Figure 4A and B). It was expected a bilateral concentric activation of RA, that was active in 100% of repetitions, and of GM, which was recruited in L portion in 86% and R portion in 79% of repetitions. However, it was also observed non-expected EMG activation of left longissimus dorsi (LLD) and right longissimus dorsi (RLD) with activities in 57% and 50% of trials, respectively. In spite of that, these non-expected bilateral activations of LD presented a tendency for mean duration of 0.48 and 0.34 sec for each antimere, L and R respectively. Lower than observed for RA and GM, which were of 1.77, 2.05, 1.48 and 1.69 sec for each antimere (Table 5). GF demonstrated a tendency to follow GM, RA and LD sequence of activation and had reactivation of these during the execution, like previous maneuvers (Table 6). In TT it was expected that the force created caudroventrally would cause loss of balance, stimulating the horse to change its center of mass cranially with activation of LD, RA and GM (Figure 5). Activation pattern was closest to the expected. L and R antimeres were active in 79% for LD, 100% and 93% for RA and 100% for GM.

Table 5. Muscle activity during global flexion of each horse (1 to 7) in repetitions (A and B). Compared by the expected percentage (%), mean and standard deviation (SD), in seconds, between the mean duration (total duration divided by the number of activations) of repetitions (A and B) for each horse in each muscle and total. Where: LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis); RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius); O (active); X (inactive); % (expected observed quantity/ 14)

Global flexion (digital stimulus in the sternum and ischiatic tuberosity)																	
Horse		1		2		3		4		5		6		7		Expected	%
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	Mean ± SD (total)	
Muscles	**LLD**	X	X	O	X	O	O	O	O	O	O	O	X	X	X	**X**	43
	Mean±SD	0.00±0.00		0.24±0.33		0.70±0.42		1.12±0.33		1.04±0.13		0.25±0.35		0.00±0.00		**0.48±0.50**	
	RLD	O	X	O	O	O	X	O	O	X	X	O	X	X	X	**X**	50
	Mean±SD	0.13±0.18		0.50±0.00		0.40±0.57		1.13±0.27		0.00±0.00		0.20±0.28		0.00±0.00		**0.34±0.43**	
	LRA	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	1.84±1.31		0.95±0.45		1.15±0.21		2.28±0.73		1.95±0.09		0.64±0.08		3.64±0.08		**1.77±1.07**	
	RRA	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	1.76±0.88		2.75±3.05		1.03±0.67		2.92±1.65		1.29±0.76		1.01±0.71		3.61±0.05		**2.05±1.45**	
	LGM	O	X	O	O	O	O	O	O	O	O	O	O	O	X	**O**	86
	Mean±SD	0.28±0.40		5.55±0.55		0.45±0.07		0.74±0.51		1.54±0.66		1.20±0.62		0.63±0.89		**1.48±1.82**	
	RGM	O	X	O	O	O	O	O	O	O	X	O	O	O	X	**O**	79
	Mean±SD	0.35±0.49		4.95±0.78		1.05±0.35		1.49±0.56		0.97±1.37		2.37±0.22		0.66±0.93		**1.69±1.62**	

Table 6. Muscle activation sequence during global flexion of each horse (1 to 7) in repetitions (A and B). Where LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis; RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius)

Global flexion (digital stimulus in the sternum and ischiatic tuberosity)																	
Horse		1		2		3		4		5		6		7			
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	Predominantly		
Sequence	**1°**	LRA	LRA	LGM	LGM	LGM	RGM	RGM	RGM	RGM	LGM	LGM	RRA	LGM	LRA	LGM		
	2°	RRA	RRA	RGM	RGM	RRA	LRA	RGM	LRA	LGM	LRA	LLD	LGM	RGM	RRA	RRA		
	3°	LGM		RRA	RRA	LLD	RRA	RRA	LLD	LRA	LLD	RLD	RGM	RRA		RRA		
	4°	RGM		LRA	LRA	LRA	LGM	RGM	RLD	RRA	LGM	LRA	LRA	LRA		LRA		
	5°	RLD		LLD	LRA	LGM	LLD	LGM	RRA	LLD	RRA	RRA	LGM			LLD	RRA	LGM
	6°	LRA		RRA	RLD	RLD		LGM	LGM			RGM	RRA			RLD	RRA	LGM
	7°	RRA		LRA		RGM		LLD	RGM			LLD				LLD	RGM	
	8°			LRA		RRA		LGM	LRA			RLD				LRA		
	9°			RLD				LRA	LLD			LRA				LRA		
	10°			LLD				LLD	RLD			RRA				LLD		
	11°			RLD				RLD	LGM			RLD				RLD		
	12°							LLD				RRA				LLD	RRA	
	13°							RLD								RLD		

Mean duration was relatively stable during TT, varying from 0.63 to 2.09 sec (Table 7). In this sequence of activation was observed a tendency to begin with GM and RA, ending with LD (Table 8). EMG is in constant development and study parameters can be relevant to evaluate specific muscle activities, as well as synergic and antagonist activities. With the impossibility to execute mVIC to allow the EMG data normalization and a trustworthy comparison, this article focused on describing, analyzing and discussing variables of active and inactive distribution, mean duration and sequence activation. Peham *et al*. (2001) described that LD is the most important for dorsiflexion when activated bilaterally. It is also described by Robert *et al*. (2002); Licka *et al*. (2009) as a muscle of multi-articular function, stabilization and antagonist to ventroflexion. Therefore, the peaks of EMG signal referents to LD in the three movements of flexion were probably by eccentric contraction not allowing a hyperflexion of trunk or concentric trying to reestablish initial rest posture. Even combination of both is possible because some repetitions showed reactivation of muscles with the passing time of data gathering, suggesting the reflexive cadency of digital stimulus applied in each movement, that is, movements were not constant and fluid in some trials.

Most probably rhythmic in sequence of flexion and extension of the back. Now in TT, LD acted in stabilization by doing isometric contraction due to the imbalance created by traction. Different than Robert *et al*. (2002) found, in which was observed an increase in the RA of stabilizing nature at trot. Reflecting in smaller movement in the sagittal plane of the thoracolumbar section. In the present study, the activation of RA suggests that it had a concentric role during movement execution contributing to flexion and elevation of the back. Although its stabilizing nature can be observed at TT and the ending of positions in flexion movements. So, it would be necessary to compare an EMG data pairing with the cinematic of the movement.

Table 7. muscle activity during tail traction of each horse (1 to 7) in repetitions (A and B). Compared by the expected percentage (%), mean and standard deviation (SD), in seconds, between mean duration (total duration divided by the number of activations) of repetitions (A and B) for each horse in each muscle and total. Where: LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis); RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius); O (active); X (inactive); % (expected observed quantity/ 14)

Tail traction																	
Horse		1		2		3		4		5		6		7		Expected	%
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	Mean ± SD (total)	
Muscle	**LLD**	O	X	O	O	O	O	O	O	O	O	O	O	X	X	**O**	79
	Mean±SD	0.32±0.45		0.97±0.31		1.13±0.53		0.58±0.08		0.57±0.01		0.83±0.28		0.00±0.00		**0.63±0.44**	
	RLD	X	X	O	X	O	O	O	O	O	O	O	O	O	O	**O**	79
	Mean±SD	0.00±0.00		0.32±0.45		0.98±0.74		1.06±0.69		0.69±0.08		1.16±0.13		1.42±0.76		**0.8±0.61**	
	LRA	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	0.58±0.11		1.85±0.58		0.45±0.07		0.87±0.20		0.59±0.06		1.02±0.60		4.44±0.83		**1.40±1.40**	
	RRA	O	O	O	O	O	O	O	O	O	X	O	O	O	O	**O**	93
	Mean±SD	0.89±0.42		0.90±0.11		0.25±0.07		0.73±0.22		0.75±1.06		1.03±0.45		2.94±1.07		**1.07±0.95**	
	LGM	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	0.93±0.16		0.75±0.35		1.42±0.54		2.41±1.49		0.93±0.48		0.73±0.30		1.98±1.38		**1.30±0.88**	
	RGM	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	100
	Mean±SD	1.60±0.04		1.29±1.02		1.49±1.29		3.19±0.74		2.69±0.18		0.91±0.31		3.44±1.70		**2.09±1.19**	

Table 8. Muscle activation sequence during tail traction of each horse (1 to 7) in repetitions (A and B). Where LLD (left longissimus dorsi); RLD (right longissimus dorsi); LRA (left rectus abdominis); RRA (right rectus abdominis); LGM (left gluteus medius); RGM (right gluteus medius)

Tail traction																	
Horse		1		2		3		4		5		6		7			
Repeat		A	B	A	B	A	B	A	B	A	B	A	B	A	B	**Predominantly**		
Sequence	**1°**	RRA	LRA	RLD	RRA	RRA	RGM	RGM	LLD	RGM	RGM	RRA	LLD	RGM	RLD	RGM		
	2°	LGM	LGM	LRA	LLD	LRA	LGM	LLD	LGM	LGM	LGM	LGM	RLD	RLD	RGM	LGM		
	3°	RGM	RGM	LLD	RRA	LLD	RLD	RLD	RGM	LRA	LRA	RLD	LRA	LGM	RRA	RLD	LRA	RGM
	4°	RRA	RRA	RRA	RGM	RLD	LGM	RRA	LGM	RLD	RLD	LLD	RRA	LRA	LRA	RRA		
	5°	LGM	LGM	LGM	LRA	RGM	RGM	LGM	LRA	LLD	LGM	RRA	RGM	RRA	LGM	LGM		
	6°	LLD		RGM	RRA	RGM	RRA	LLD	RGM	RRA	LRA	LRA	LGM		RGM	RGM		
	7°	LRA		LGM	LGM	LGM	LGM	LRA	LLD	LRA	LLD	RGM	LGM		LGM	LGM		
	8°	LRA				LLD	LLD	RRA	LRA	LGM		r	LLD		RRA	LLD	RRA	
	9°					RGM	RLD	RLD	RLD	LLD			RLD			RLD		
	10°						LRA	LLD	LRA				LRA			LRA		
	11°						LLD	RLD	RRA				RRA			RRA		
	12°								LLD							LLD		

Robert *et al*. (1999) associated EMG activity of GM with movement of hip extension during trot of equines in a treadmill. This justifies the observation of GM activity during the flexions, mainly at LLSF and GF, which provoke hip joint extension. During TT was observed the nearest activity to the expected. However, it was the only one expected to activate all muscles. Where the others got further from expected, that is, TLF, LLSF and GF provided bigger activation of muscle than expected, mainly LD in the three flexions and from GM at TLF. Abercromby *et al*. (2007) also found divergent results from expected in humans at vibrating platforms. They raised the possibility that this unexpected variation could be coming from involuntary reflexive activity to tonic vibration added to a variation of voluntary muscle activity to do exercises at the platform with vibrations in different directions. They also raised that it could be a reflex from posture control during exercise execution. Similar to what we suspect that occurs during the flexions to activate equine's core, which it had a tendency to activate bilaterally LD in an eccentric way to confine the flexion or in a concentric way to reestablish initial rest posture of the back.

These unexpected muscle activities and sequence of non-standardized activity, not only individually but also between repetitions of the same subject during the same maneuvers, were also described by Ludvig and Larivière (2016). They also observe that EMG analysis varied between individuals and repetition in a study about reflexive EMG activity and external disturbances in humans. To deal with this variation, Ludvig and Larivière (2016) selected the most consistent trials calculating the mean squared error of each individual per muscle, where less consistent results were removed if they provided an improvement in consistency outcome by 50%. Although this calculus was not applied in the present study, a data triage was performed where two repetitions with the highest number of sensors without interference were analyzed. However, this calculus can be interesting for future studies.

On the other hand, mean duration suggests that these unexpected muscle activations were less relevant than contraction of the expected muscles that had superior mean durations. This challenge to interpret electromyographic data without the normalization by mVIC is also reported by Valentin and Zsoldos (2016). To avoid this normalization by the mVIC, in human studies of vibrational platforms exercises, Abercromby *et al*. (2007) compared EMG values of RMS found during the vibrational exercises with the basal individual condition, without vibration. This could be interesting to apply in animal EMG studies. Additionally, to this variability of active or inactive, there was a lack of synchrony in the activation sequence and of the average duration, which showed some tendencies to have high standard deviation of mean values. This may suggest how these maneuvers can activate the equine core providing variable muscle recruitment and possibly working the body balance of the horses. Similar to Jarvinen *et al*. (2003) which exercises in vibrational platforms were capable of improving immediate and transitionally physical performance, including isometric force, capability to jump and body balance of healthy adult humans.

Robert *et al*. (2002) in a locomotion study with different speeds on the treadmill found that most of muscle activity duration were not significantly affected by the increase of speed at trot and it was possible to correlate muscle activity with phases of the gait by analysis paired cinematic. Although these maneuvers to activate equine core are not extremely standardized and cyclic like the equine gait, it was also expected uniform results. However, Ludvig and Larivière (2016) in human studies about reflexive response of postural disturbances demonstrated that reflexive EMG activity did not correlate with estimated reflexive mechanical responses. Therefore, it is possible that these four maneuvers can activate the equine core to work more proprioceptive capabilities, posture and stability than just the mechanical movement execution on its own. Ludvig and Larivière (2016) also found that reflexes to disturbance activated six muscle groups in the human torso, not only flexors but extensors as well. However, some muscles and temporal spaces registered higher reflexive EMG activity to disturbance than others, similarly to what is described in the present research.

To future papers, the paired analysis of cinematic and surface EMG can contribute to correlation between muscle activity with movement provided during maneuvers execution to activate and stretch the equine core (Peham *et al*., 2001). Besides, it can help in the biomechanics understanding regarding synergism and antagonism during execution of different maneuvers in horses. Like in humans, studies about the behavior of core activation in different physical activities can improve training strategies (Borghuis *et al*., 2008) and possibly reduce the risk of lesions related to high level performance (Zsoldos *et al*., 2010).

CONCLUSION

From this research can be deduced that movements of TLF, LLSF, GF and TT were capable of producing punctual and transitory muscle activities above from the expected, showing the importance of these maneuvers for activation of LD, RA and GM in horses. LLSF and TT were the most efficient in activating those three equine core muscles. However, the high variability of occurrence, duration and sequence, may possibly be due to different breeds, temperaments, levels of proprioception. Or because of maneuver`s own nature, suggesting the importance to do more than two repetitions with longer than five sec of reflex stimulation. The hypothesis is with these increases, gradual and respecting the individual limits of each horse, could activate more muscle groups.

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