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Comparison of the electromyographic activity of the anterior trunk during the execution of two Pilates exercises – teaser and longspine – for healthy people

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ABSTRACT

This study compared abdominal electromyographic (EMG) activity during the performance of Pilates' exercises. 16 females participated in the study. EMG signals of the rectus abdominis (RA) and external oblique (EO) were recorded during Longspine performed on the mat, Cadillac, and Reformer and the Teaser performed on the mat, Cadillac, and Combo-chair. Values were normalized by the EMG peak of a dynamic task and divided in concentric and eccentric phases. Longspine performed on the mat increased EO activity in the concentric phase more than on the Reformer and the Cadillac (Mean Difference (MD) = 12.2%; 95% Confidence Interval (CI) [3.36; 21.04]; $p = .04$). Differences in the eccentric phase of the RA favored the mat compared to the Reformer (MD = 5.20%; 95% CI [−0.55; 10.95]; $p = .02$). Significant differences in eccentric contraction of the RA were found for teaser exercise performed on the mat versus Cadillac (MD = 1.1%; 95% CI [−4.13; 6.33]; $p = .04$) and the mat versus the Combo-chair (MD = 6.3%; 95% CI [1.31; 11.29]; $p = .005$). Higher concentric activation values for the EO were found when the teaser exercise was performed on the Cadillac. Exercises performed on the mat required greater rectus abdominis activation.

1. Introduction

Abdominal muscles are important for maintaining proper body posture. They are responsible for stabilizing the lumbar spine during movement in order to avoid injury and pain, to support containment of the abdomen and to facilitate chest movements during breathing (Hodges et al., 2002; McGill et al., 2003; McGill, 2007; Posadzki et al., 2011). Panjabi (1992) states that the stability of the lumbar spine depends on three subsystems: control, passive and active movement.

Within the active subsystem, the abdominal oblique muscles work eccentrically to control the range of motion, while the rectus abdominis (RA) works concentrically to produce power and speed, and eccentrically to decelerate high loads (Gibbons et al., 2001; Mottram et al., 1998). Data indicate the RA muscle is recruited primarily to create trunk flexion, while the obliques are recruited to improve spinal stability, assist breathing during exercise and generate torque in lateral bending (Cholewicki et al., 1996; McGill et al., 1995; Monfort et al., 1997). Studies demonstrate the antagonist co-contraction of the abdominal muscles influences the stability of the spine during various activities (Arjmand et al., 2006; Cholewicki et al., 1996; El-Rich et al., 2004; Gardner et al., 1995; Granata et al., 2000).

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The Pilates' method is a form of exercise designed to improve flexibility, strength and posture. Pilates exercises emphasize control of body position and movement; specifically targeting trunk muscles. (Pilates and Miller, 1945; Wells et al., 2012). Exercises can be performed on the mat, Reformer, Cadillac, Combo-chair and Ladder Barrel. The difficulty of the exercise can be manipulated by changes in spring tensions or increasing the gravitational challenge (Anderson et al., 2000). Certain exercises proposed by the Pilates' method can be performed either on the mat or on the apparatus; however, changing the location where the exercise is performed modifies the biomechanical demands imposed on the body. These changes in biomechanical demands can alter the center of mass (CM) and torque moment as well as the pattern of muscle activation required to maintain posture. Despite alterations in biomechanical demands when the same exercise is performed on different apparatus, little data exist to substantiate this statement.

The use of electromyography (EMG) is the graphic representation of the electrical activity of a contracting muscle, often referred to as the motor unit action potential. EMG is a primary measure used in biomechanics for evaluating muscle activity during a specific exercise (Levine et al., 2012; Soderberg et al., 2000). However, its interpretation requires care and many factors must be taken into account (Farina et al., 2004; Merlo and Campanini, 2010; Zaheer et al., 2012). EMG has been used to measure trunk muscle activity during Pilates' exercises. Some studies have evaluated the trunk muscles in different conditions and variations. Others have demonstrated a change in the execution of the exercise or the placement of the limbs causes changes in electromyographic activity (Menacho et al., 2013; Queiroz et al., 2010; Souza et al., 2012). No research has examined the effect of Pilates exercises on muscle activation of the anterior truck muscles when performed on different apparatus.

The aims of this study were (1) to determine whether any difference exists in electrical activity of the RA and EO muscles during the longspine exercise performed on the mat, Cadillac and Reformer apparatus; (2) to assess whether electrical activity of the RA and EO muscles differ during the teaser exercise performed on the mat, Cadillac and Chair; and (3) to investigate whether differences exist in the electrical activity of the RA and OE for any of the exercises. We hypothesized that there would be a difference in EMG during differ exercises performed on the various equipment and mat.

2. Method

2.1. Subjects

Sixteen healthy females, aged between 20 and 31 years, who had been practicing Pilates for at least six months, volunteered to participate in the study. Several studies demonstrate gender differences in activation patterns and biomechanical factors. Thus, only one gender was included (Clark et al., 2003; Hanson et al., 2008; Miller et al., 2010; Youdas et al., 2007;). The mean age of the subjects was 24.3 years (SD = 3.1), mean body mass index (BMI) = 20.7 kg/m^2 (SD = 1.3) and median length of time practicing Pilates was 12 months (10–24). The study exclusion criteria included: back pain in the last six months, severe scoliosis or congenital malformation of the spine, prior back and abdominal surgeries, neurological disease, cancer and pregnancy. The participants were informed about the experimental protocol and the potential risks of the study and gave written consent prior to their participation. This study had been previously approved by the Ethics Committee of the Universidade Estadual de Londrina, PR, Brazil (#266/07).

2.2. Procedures

On the first day, a member of the research team collected anthropometric data on each subject in a standardized manner. On the second day, after an interval of at least 48 h, subjects performed a warm-up with eight repetitions of each of the following exercises: spine stretch forward, cat stretch and preparatory for set-ups. Subsequently, the abdominal muscles activation was recorded while subjects performed two traditional Pilates' exercises on the apparatus (Reformer, Cadillac and Combo-chair) and mat while abdominal muscle activation was being recorded via surface EMG. The longspine (Fig. 1) was performed on the mat, the Cadillac and the Reformer. The teaser (Fig. 2) was performed on the mat, the Cadillac and the Combo-chair. Figs. 1 and 2 illustrate the body center of mass (COM). The reason was to provide better understanding of the exercises, but COM was not taken into account in the analysis. Although the calculation is more accurate when performed in 3D, modelling was constructed in 2D through Matlab sub-routines (Version 7.0; The MathWorks Inc., 3 Apple Hill Dr, Natick, MA, USA) (Donskoi and Zatsiorski, 1988). 2D modeling was used as movements occurred only in the sagittal plane.

Each subject performed four repetitions of each exercise with a standardized rest interval of five minutes between exercises. To minimize possible differences during the execution of the exercises, a slow and self-controlled pace was proposed. Subjects performed the two phases of movement during expiration with a 3 s period between one repetition and the next, allowing subjects to inhale before starting the next movement. The order of exercises (longspine and teaser) and the condition (mat, Reformer, Cadillac or Combo-chair) was chosen randomly using a random numbers table. A professional who was trained in the Pilates' method and was an experienced as a Pilates' instructor demonstrated all exercises.

For analysis, since some differences in muscle activation patterns are found between phases, exercises were divided into concentric and eccentric phases (Portney et al., 2006). A standard 30 Hz video camera (DCR-DVD 92 Handycam Camcorder, Sony Electronics Inc, New York, NY, USA) and a video capture card connected to the computer were used to collect these data. The beginning of each phase was determined visually. The software (AcqKnowledge 4.0; BIOPAC Systems Inc, Aero Camino Goleta, CA) used enabled data synchronization. For the concentric phase of the longspine exercise, data collection began in hip flexion until hip extension with the feet toward the ceiling. For the eccentric phase of the longspine exercise, the sequence began with the thoracic spine until the person reached the starting position. With the concentric phase of the teaser exercise, subjects began with spine until weight bearing in ischia with the upper and lower limbs; eccentric phase began with the sequence of the lumbar spine until the person reached the starting position.

2.3. Description of exercises and apparatus

The Cadillac apparatus is a four-poster bed configuration with various springs and hanging bars. The Reformer apparatus is a sliding platform with springs. The subject lies down, sits or stands on the device. The Combo-chair is an equipment consisting of four springs, containing side stems and independent pedals that can be used together or separately.

Exercises performed during warm-up were: spine stretch forward, cat stretch and preparatory for set-ups. The spine stretch forward is performed in sitting. To begin, the subject inhales then exhales while stretching the spine from the anterior trunk flexion, starting with the head. The subject then inhales and maintains the stretched position. The spine articulates sequentially from tailbone to the head while the subject exhales until starting position is reached. Cat stretch: The position is kneeling on all fours. The

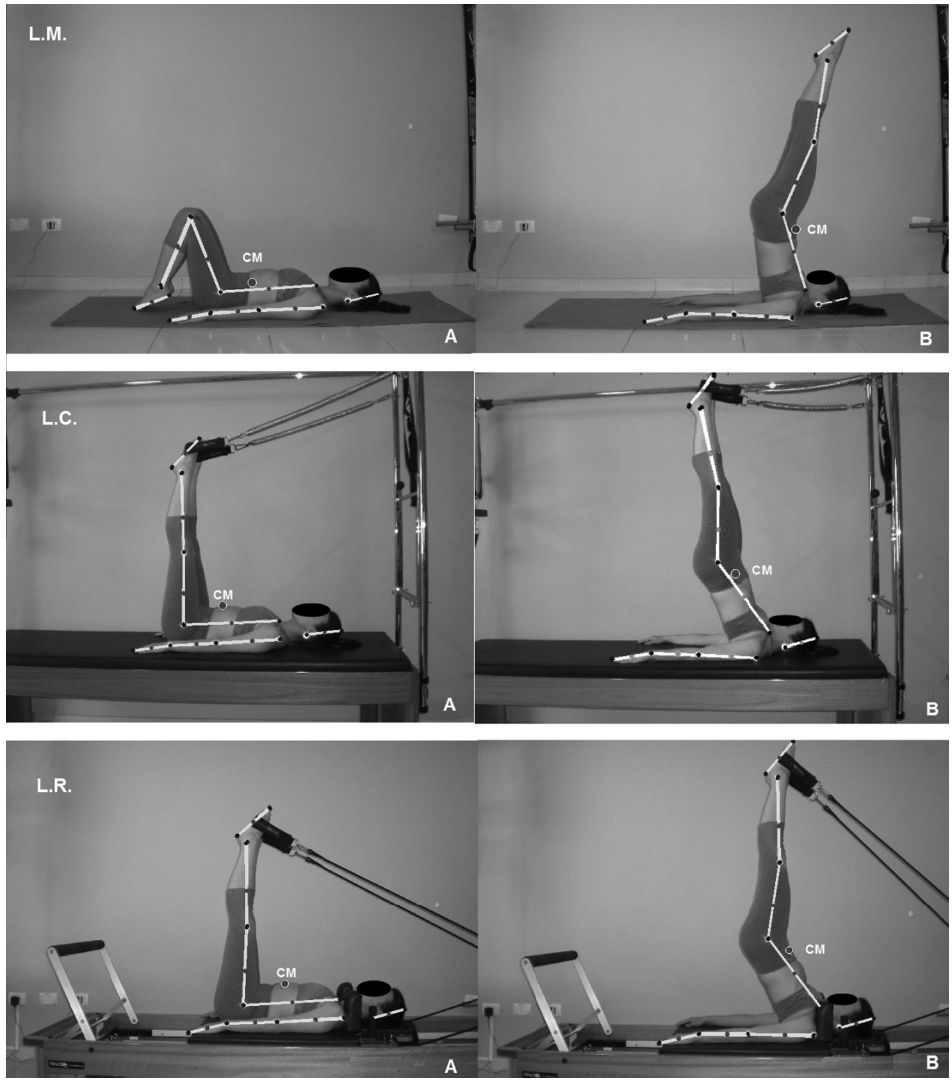

Fig. 1. Longspine exercise performed on the mat, Cadillac and Reformer apparatus. L.M. = longspine on the mat, L.C. = longspine on the Cadillac, L.R. = longspine on the Reformer. A = initial movement and B = final movement.

subject inhales then exhales, curving the spine up towards the ceiling, allowing head to drop and tailbone to tuck under. Subject inhales keeping head and shoulders relaxed then exhales, returning the spine to starting position. Preparatory for set-ups: The position is in supine, pelvis and spine neutral, knees flexed and feet on the mat. Subject inhales then exhales, stabilizes the scapulae, contracts abdominals and flexes thoracic spine, reaching arms off mat, until shoulders are level. Then subject inhales, maintaining the abdominal contraction and exhales, rolling upper body down to the mat whilst lowering arms simultaneously.

Exercises performed during data collection were the teaser and longspine. teaser: The starting position was in supine. The oblique muscle contraction pulls the pelvis to the rib cage, resulting in a slight posterior pelvic tilt with a slight flexion of the lumbar spine. The legs set parallel, adducted, with knees flexed and ankle in plantiflexion. Arms remain stretched above the head, maintaining the contact of the lower and posterior ribs for support and stabilizing the scapula. During the exercise, the subject inhales and exhales, maintaining the stabilization of the scapula and raising the arms up high, then bending the column sequentially away from the support, one vertebra at a time, balancing the weight behind the hamstrings, raising the arms towards the feet, with a slight flexion of the lumbar and thoracic spine. Simultaneously, the subject extends the knees. Subject stays in balance, raising the arms to ear height, then inhales and exhales. The subject starts backing away the anterior superior iliac spines from the femur and sequentially down the trunk on the support in imprint position, and arms at ear height. Variations: on the Cadillac, the position of the upper limbs varies. Subject holds the tower bar with the elbows in approximately 30° of flexion, and shoulders aligned with the tower bar. In the execution, the subject pushes the tower bar up, extending the elbows while performing the same movement as above. On the Combo-chair, the upper limbs position varies, with elbows straight and hands facing backward, holding the bar at the lowest possible height (close to the ground). Subject breathes in and out performing the movement mentioned above with the exercise is performed on the ground. Longspine: The starting position was in supine, keeping the imprint position. Subject sets legs parallel and adducted, extended upward to 90° hip and ankle plantar flexion. Arms beside the body, extended with palms down, and scapula stabilized. Subject inhales, gently flexing the hip, then sequentially articulates the column, removing it from the support, starting from the coccyx and working to the thoracic region. Then exhales extending the hips and raising the legs toward the ceiling. Weight is still supported in the thoracic region, keeping spine flexion. Again the subject inhales, staying in position, fingers toward the ceiling, without supporting the weight of the cervical spine. Then exhales, retaining the hip as much as

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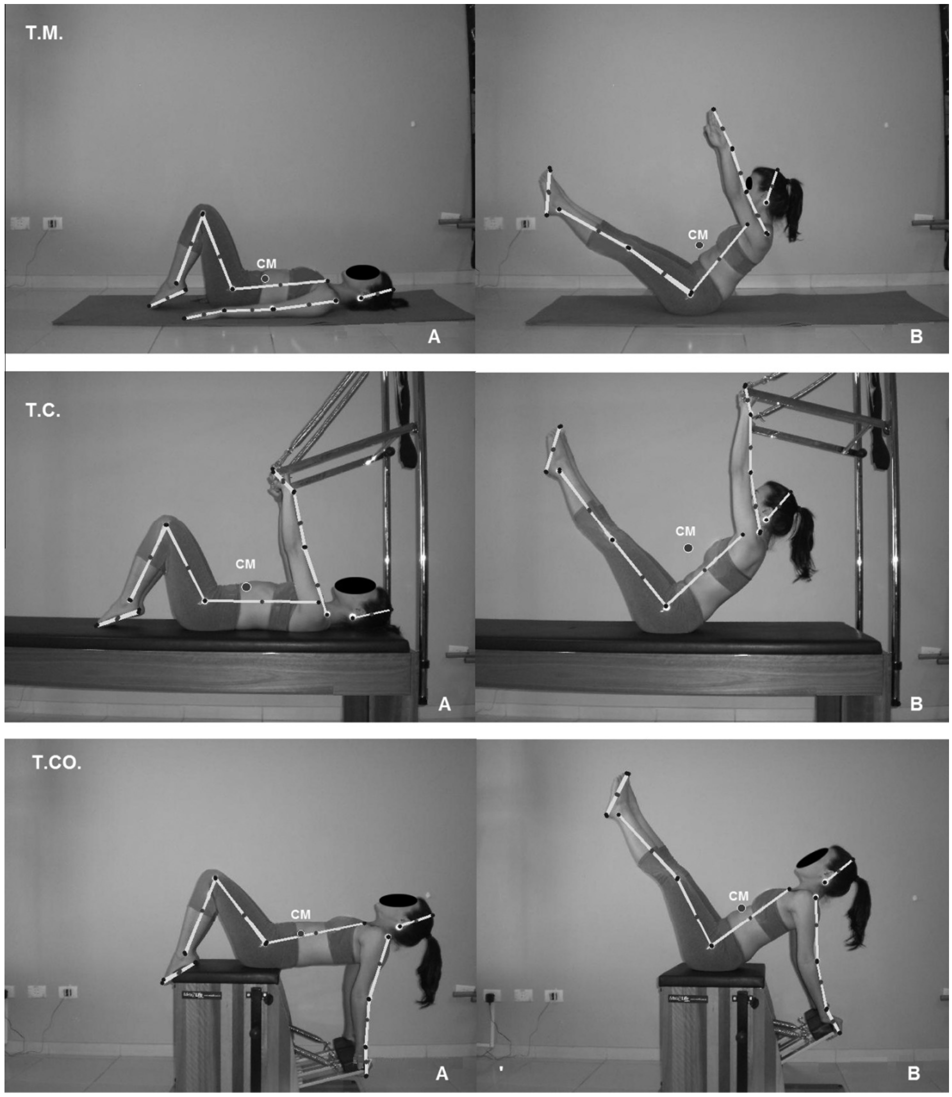

Fig. 2. Teaser exercise performed on the mat, Cadillac and Combo-chair apparatus. T.M. = teaser on the mat, T.C. = teaser on the Cadillac, T.CO. = teaser on the Combo-chair. A = initial movement and B = final movement.

possible, the column sequentially articulated, a vertebra at a time, maintaining the imprint position while returning to the starting position. Variations: Changes are the handle up and spring that are used on both the Cadillac and the Reformer. After placement of the foot straps, subject performs the above movement in the same way as when the exercise is performed on the Reformer, but attempt to control the instability of the cart, so that it does not change position.

2.4. Data analysis

An eight-channel electromyography system was used to obtain biological signals. The system consist of a signal conditioner with a band pass filter cut-off frequencies at 20–450 Hz, active bipolar electrodes were connected to a high impedance preamplifier gain of 2000x and a common mode rejection ratio >120 dB (MP150; BIOPAC Systems Inc., Aero Camino Goleta, CA). All data were collected using specific software for acquisition and analysis, throughout the execution of the exercises. Analog-to-digital conversion (16 bits) was set up with an anti-aliasing filter and a sampling frequency of 2 kHz for each channel and an input range of 10 mV.

An experienced researcher shaved and prepared the skin with 70% alcohol and positioned the electrodes bilaterally on the rectus abdominis (RA) and external oblique (EO) muscles. The electrode positions were: 3 cm lateral to the umbilicus for the rectus abdominis and 15 cm lateral to the umbilicus at the transverse point of the umbilicus for the external oblique muscle, taking muscle fiber direction into account (Juker et al., 1998). Electrodes were fixed to the skin with adhesive tape to prevent movement during the execution of the exercises. The interelectrode (center-to-center) distance was 2 cm (Soderberg et al., 2000). The reference electrode was placed on the nondominant wrist.

After filtering the data via software, the signal was separated into concentric and eccentric phases, established through kinematic data. The values of root-mean-square (V_{RMS}) for each muscle, exercise and repetition were obtained using the formula: $V_{RMS} = \sqrt{\frac{1}{N}\sum_{n=1}^{N}(w[n])^2}$[Volts], where $w[n]$ is the n-th amplitude sample of the non-rectified EMG signal, and$N$is the number of samples in the considered time interval. The peak activation, within each contraction phase, was obtained from the total RMS and used to normalize the signal. Furthermore, as each subject performed the exercise for different lengths of time, the signal was windowed in time percentage (i.e., the signal was separated into 10% windows of the total exercise time). An average of these 10 windows was performed to obtain the RMS value of each repetition. All EMG data were analyzed using Matlab sub-routines (Version 7.0; The MathWorks Inc., 3 Apple Hill Dr, Natick, MA, USA). Fig. 3 (illustrative only) represents the processing of the signals.

Normalization by the EMG peak of a dynamic task was chosen because some authors have noted greater efficiency and applicability of such standards during dynamic activities. This process shows less variability when compared to other methods (Yang et al., 1984; Kadaba et al., 1989; Knutson et al., 1994). Furthermore, some researchers have recommended using the mean or peak EMG value from the dynamic contraction as this process reduces the intersubject coefficient of variation (Knutsson et al., 1979; Vander Linden et al., 1991; Soderberg, 2000).

2.5. Statistical analysis

Numerical variables were tested for normal distribution using the Shapiro–Wilk test. Differences between the right and left sides and between the exercise conditions were analyzed using analysis of variance with repeated measures (ANOVA). Muscle location was considered an intra-subject factor, while the condition of the exercise was considered a between-subjects factor. The Mauchly test of sphericity W was applied and when violated, technical corrections were made using the Greenhouse-Geisser test. When the F test was significant, Tukey's test for analysis by multiple comparisons was applied. The mean difference and 95% CI were applied in the comparison analysis. Statistical significance was set at 5%. Analyses were performed using SPSS® (Version 15; SPSS Inc., 233 S Wacker Dr, 11th Fl, Chicago, IL, USA).

3. Results

There was no difference between the right and left sides of any muscles, so for comparisons between conditions, the average values of the left side were considered.

3.1. Longspine exercise

When comparing RA and EO during the concentric phase no differences were found between muscle activations in any condition. Comparing EO muscle activation during the mat and reformer, a statistically significant difference was found suggesting the EO was more activated in the mat condition than Reformer (Mean Difference (MD) = 12.2%; 95% Confidence Interval (CI) [3.36; 21.04]; $p = .04$) (Table 1).

In the analysis of the eccentric phase, there were no significant differences in muscle activation in any condition. However, there was a significant difference in RA muscle activation for exercise performed on the mat versus the Cadillac (MD = 5.20%; 95% CI [-0.55; 10.95]; $p = .02$). Specifically, RA muscle was activated more in the mat condition than the Cadillac (Table 2).

3.2. Teaser exercise

During the concentric phase, there was a statistical difference in favor of the EO in the Cadillac (MD = 31.20%; 95% CI [18.61; 43.79]; $p = .02$) and Combo-chair (MD = 25.60%; 95%CI [13.34; 37.86]; $p = .04$) compared to the RA (Table 3). No differences were found when compared conditions (mat, Cadillac, Combo-chair) (Table 4).

In the analysis of the eccentric phase, no differences were found between muscle activations of the RA and EO in any condition. However, differences in RA muscle activation existed based on condition. Specifically there was a significant difference in RA activation for the mat in comparison with the Cadillac (MD = 1.1%; 95% CI [−4.13; 6.33]; $p = .04$) and the mat in comparison with the Combo-chair (MD = 6.3%; 95% CI [1.31; 11.29]; $p = .005$). Comparing the Cadillac versus the Combo-chair, when evaluating the EO muscle, the EO was most activated in the Cadillac condition (MD = 13.80%; 95% CI [−0.99; 28.59]; $p = .02$) (Table 5).

4. Discussion

The primary aim of this study was to compare the activation of the superficial abdominal muscles during the performance of the same exercise in different conditions: mat or apparatus. The activation of the rectus abdominis and external oblique muscles during each exercise were compared within each phase (concentric and eccentric).

During the longspine exercise, higher muscle activation was found for the RA when performed on the mat. These findings do not corroborate existing data in the literature. Vera-Garcia et al.

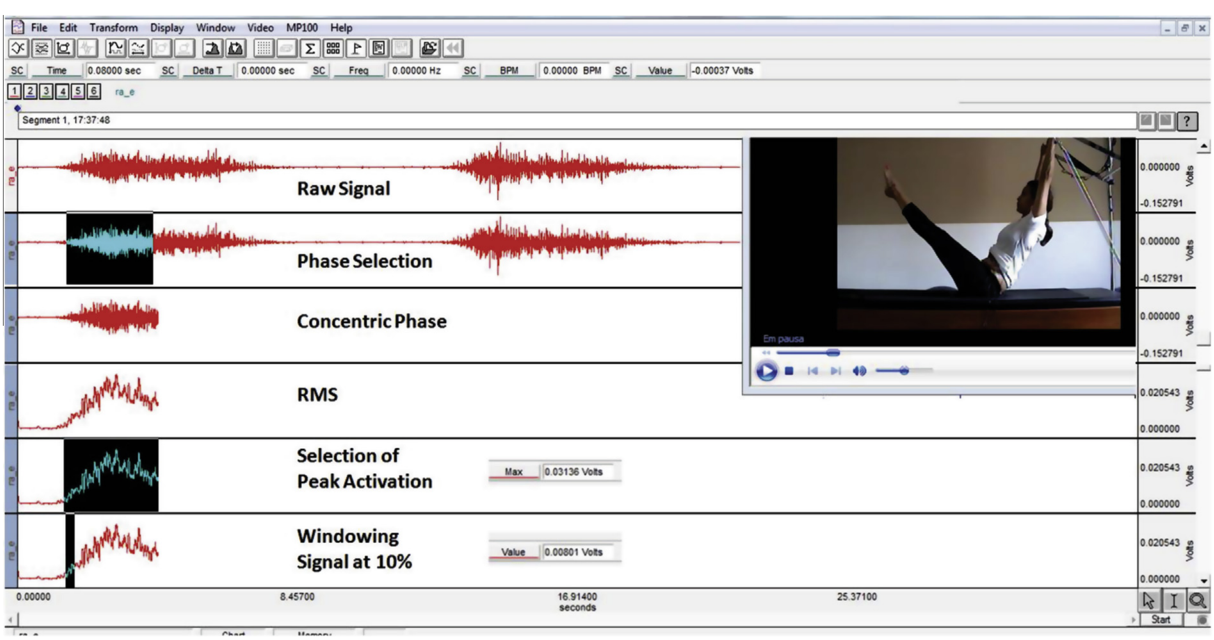

Fig. 3. Details of signal processing.

Table 1
Comparison of normalized RMS values between conditions (mat, Cadillac and Reformer) in the concentric phase of longspine.

Muscle	Condition			MD [95% IC]; p		
	Mat	Cadillac	Reformer	C1	C2	C3
RA	23.5 (9.7)	16.7 (7.8)	11.8 (7.4)	6.80 [0.70;12.90]; 0.97	11.70 [5.72;17.68]; 0.37	4.90 [−33.49;43.29]; 0.54
EO	26.2 (14.6)	20.0 (11.8)	14.0 (10.6)	6.20 [−3.0;15.40]; 0.41	12.20 [3.36;21.04] **0.04**	6.0 [−1.77;13.77] 0.72

The values (%) are presented in mean and standard deviation. The significant difference ($p < .05$) is in bold. Abbreviations: RA = rectus abdominis; EO = external oblique; MD = mean difference; 95% IC = 95% of confidence interval; C1 = comparison between mat × Cadillac; C2 = comparison between mat × Reformer and C3 = comparison between Cadillac × Reformer.

Table 2
Comparison of normalized RMS values between conditions (mat, Cadillac and Reformer) in the eccentric phase of longspine.

Muscle	Condition			MD [95% IC]; p		
	Mat	Cadillac	Reformer	C1	C2	C3
RA	16.7 (8.4)	11.5 (8.2)	7.7 (4.9)	5.20 [−0.55;10.95] **0.02**	9 [4.23;13.77] 0.95	3.80 [−0.88;8.48] 0.88
EO	20.3 (11.2)	10.8 (5.2)	10.9 (6.0)	9.50 [3.45;15.55] 0.75	9.40 [3.17;15.63] 0.15	−0.10 [−3.99;3.79] 0.92

The values (%) are presented in mean and standard deviation. The significant difference ($p < .05$) is in bold. Abbreviations: RA = rectus abdominis; EO = external oblique; MD = mean difference; 95% IC = 95% of confidence interval; C1 = comparison between mat x Cadillac; C2 = comparison between mat x Reformer and C3 = comparison between Cadillac x Reformer.

Table 3
Comparison of normalized RMS between the RA and EO muscles in the concentric phase of the teaser.

Muscles_Conditions	$\overline{X}$(DP)	*p*
LRA_mat	31.2 (12.7)	0.32
LEO_mat	53.2 (26.5)	
LRA_cad	23.3 (7.1)	**0.02**
LEO_cad	54.5 (24.7)	
LRA_chair	23.3 (8.6)	**0.04**
LEO_chair	48.9 (23.5)	

Significant differences ($P < .05$) are in bold. Abbreviations: $\overline{X}$ **=** mean (%), SD = standard deviation; LRA = left rectus abdominis; LEO = left external oblique; cad = Cadillac and chair = Combo-chair.

(2000) reported exercises performed on movable surfaces (such as the reformer) can double the electrical activity of the abdominal muscles. One possible explanation for higher muscle activation of the RA when performed on the mat might result from the fact that this condition offers no external support. On the reformer apparatus, foot straps support the lower limbs and allow the elastic force of the spring to act in the direction of hip flexion, facilitating movement and suggesting a possible contribution of hip extensor muscles to overcome resistance. Thus, greater muscle activation can be explained by the increased need to maintain body stability. To enhance stability, the motor control system selects the EO more than any other abdominal muscle (Vera-Garcia et al., 2000), leading to greater activation of the EO when compared to the RA muscle. It is noteworthy that in the longspine exercise, trunk flexion occurs with the movement of the pelvis. Studies have demonstrated a greater activity of the EO is expected in this situation (Escamilla et al., 2006; Konrad et al., 2001; Willett et al., 2001).

For the teaser exercise, higher truck muscle activation was found on the mat, followed by the Cadillac and finally the Combo-chair. This exercise consists of upper trunk and pelvic movements. There is no consensus in the literature about the pattern of muscle activation in exercises of the upper trunk. While Clark et al. (2003) and Escamilla et al. (2006) found increased activation of the RA, Sarti et al. (1996), Willett et al. (2001) and Piering et al. (1993) found no differences in muscle activation.

Exercises performed in supine with pelvic movement demonstrate greater activation of the EO (Vera-Garcia et al., 2011). Perhaps the lower activation of the RA during this exercise is related to assistance by the elastic coefficients of the springs for the upper limbs on the Cadillac and Combo-chair. The assistance of the springs could explain the greater trunk muscle activation on the

Table 4
Comparison of normalized RMS values between conditions (mat, Cadillac and Combo-chair) in the concentric phase of teaser.

Muscle	Condition			MD [95% IC]; p		
	Mat	Cadillac	Chair	C1	C2	C3
RA	31.2 (12.7)	23.3 (7.1)	23.3 (8.6)	7.90 [0.77;15.03]; 0.13	7.90 [0.38;15.42]; 0.97	0.0 [−5.46;5.46] 0.98
EO	53.2 (26.5)	54.5 (24.7)	48.9 (23.5)	−1.30 [−19.05;16.45]; 0.99	4.30 [−13.05;21.65]; 0.97	5.60 [−11.11;22.31]; 0.99

The values (%) are presented in mean and standard deviation. Abbreviations: RA, rectus abdominis; EO, external oblique; MD, mean difference; 95% IC, 95% of confidence interval; C1, comparison between mat x Cadillac; C2, comparison between mat × Chair; C3, comparison between Cadillac × Chair.

Table 5
Comparison of normalized RMS values between conditions (mat, Cadillac and Combo-chair) in the eccentric phase of teaser.

Muscle	Condition			MD [95% IC]; *p*		
	Mat	Cadillac	Chair	C1	C2	C3
RA	22.4(8.7)	21.3(6.2)	16.1(5.3)	1.10 [−4.13;6.33]; **0.04**	6.30 [1.31;11.29]; **0.005**	5.20 [1.20;9.20]; 0.93
EO	43.8 (25.3)	44.1(24.6)	30.3(17.5)	−0.30 [−17.59;16.99] 0.95	13.50 [−1.57;28.57]; 0.10	13.80 [−0.99;28.59]; **0.02**

The values (%) are presented in mean and standard deviation. The significant difference ($p < .05$) are in bold. Abbreviations: RA = rectus abdominis; EO = external oblique; MD = mean difference; 95% IC = 95% of confidence interval; C1 = comparison between mat x Cadillac; C2 = comparison between mat × Chair and C3 = comparison between Cadillac × Chair.

mat, since the subject does not receive any external support when exercising on the mat. When performing the exercise on the mat, the positioning of the upper limbs influences the load. According to Levine et al. (1997), the load will be reduced if the arms are positioned beside the body or crossed over the chest, and will increase if the arms are extended away from the body.

Studies have classified electrical muscle activations as follows: 0–20% lower activation, 21–40% moderate activation, 41–60% high activation and above 60% very high activation (DiGiovine et al., 1992; Escamilla et al., 2010). Data suggest that exercises requiring muscle activations in the low to moderate range produce an endurance effect when multiple repetitions are performed. Exercises which produce high muscle activation result in a strengthening effect (Escamilla et al., 2010). Regardless of the statistical differences in muscle activation noted for the longspine exercise performed on mat, the activation can be classified as moderate, while muscle activation during exercise on the other devices resulted in low levels of activity. As for the teaser exercise, in all conditions the RA muscle was activated moderately while the OE was highly activated.

This study has some limitations. First, the synchronization between EMG signal and kinematic data was performed manually. Secondly, the results of this study cannot be generalized to other populations that are not comprised of healthy adult women subjects. Third, the differences between activation values may be affected by different degrees of attenuation of the EMG signal by subcutaneous tissue in the different postures.

These findings can be used to inform the best condition (mat, apparatus) and muscle activation phase for individuals familiar with Pilates. The data suggest the longspine exercise should begin with the Reformer, and progress to the Cadillac and, finally the mat whether this exercise is being recommended as part of a rehabilitation program or to train healthy individuals. Whereas, the teaser exercise should be begin on the Combo-chair, followed by the Cadillac and finally the mat. These findings suggest both exercises demonstrated greater muscle activation when performed on the mat. However, it is important to note that Pilates performed on the mat has a higher degree of difficulty for beginners or individuals who are in the process of rehabilitation.

5. Conclusion

These two Pilates exercises performed in the mat required greater activity of the EO and RA muscles. This fact should be considered when making recommendations about spine stabilization or strength training programs. The external oblique muscle is more activated than the rectus abdominal muscle during the teaser exercise when executed on the Cadillac and Combo-chair. During the longspine exercise, the external oblique muscle and rectus abdominal are more activated on the mat, in both the concentric and eccentric phases respectively.

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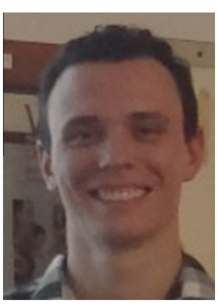

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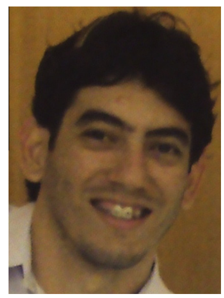

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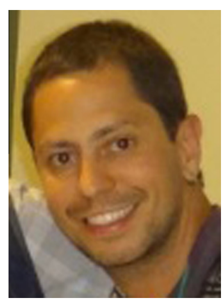

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