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DIAGNOSTIC METHODS: Mentored Research: Original Research Study

Electromyographic evaluation of trunk core muscles during Pilates exercise on different supporting bases

Ana C. Panhan [a, *], Mauro Gonçalves [b], Giovana D. Eltz [b], Marina M. Villalba [b], Adalgiso C. Cardozo [b], Fausto Bérzin [a]

[a] *Department of Morphology (Anatomy), Piracicaba Dental School, UNICAMP, Piracicaba, São Paulo, Brazil*
[b] *Department of Physical Education, São Paulo State University, UNESP, Rio Claro, São Paulo, Brazil*

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ABSTRACT

Objective: To evaluate the electromyographic (EMG) activity of the rectus abdominis (RA) and internal oblique (IO) muscles during Pilates exercise on different trunk supporting bases.
Methods: Sixteen female Pilates practitioners participated in the study. EMG of the RA and OI muscles was evaluated during the double leg stretch (DLS) exercise on three different supporting bases — mat, long box, and short box. Trunk stability varies according to the size and type of the base. To normalize the data, the RMS value (EMG) obtained during the DLS exercise was divided by the RMS value from the torque test — the maximal voluntary isometric contraction (MVIC) — and multiplied by 100 (%MVIC). One-way repeated-measured analysis of variance (ANOVA) and Bonferroni tests were used to compare data concerning the supporting bases and Student t-test regarding the muscles ($p < 0.05$).
Results: The comparison among the bases involving each muscle — RA or IO ($p < 0.05$) — showed significant difference (%MVIC) between the mat and the short box. No significant difference was observed between the muscles concerning the exercise on the mat ($p = 0.9266$), on the long box ($p = 0.5113$) and on the short box ($p = 0.2972$).
Conclusion: The short box increased the activity of the rectus abdominis and internal oblique muscles during exercise. The DLS exercise was able to challenge the stability of the trunk and thus recruit its stabilizer and mobilizer muscles at the same intensity.

1. Introduction

The Pilates method is a physical exercise program based on "contrology," defined by Joseph Pilates as the conscious control of all body movements and complete coordination of body, mind, and spirit. It provides practitioners with physical and mental well-being (Pilates and Miller, 1945). This program involves exercises that improve stretching, strength and proprioception, all of which provide better posture, muscle control, and breathing (Muscolino and Cipriani, 2004; Panelli and De Marco, 2009). It is widely used to prevent and treat muscle and joint lesions (Blum, 2002; Natour et al., 2015).

Pilates exercise is basically aimed at the core muscles — rectus abdominis, internal oblique, and transverse abdominal muscles — which are partially responsible for spinal stability (Silva et al., 2009). The core is an integrated unit composed of 29 pairs of muscles that support the hip-pelvic-lumbar complex (Akuthota et al., 2008). It is directly related to the Pilates method, whose exercises aim to improve the strength and dynamic control of such muscles.

The Pilates method includes two categories — mat and apparatus, both of which recruit the abdominal muscles (frontal core muscles). Exercises on the mat use body weight and gravitational force as a form of resistance (Muscolino and Cipriani, 2004). Accessories such as the magic circle, neck stretcher, foot corrector, toe exerciser, push up device, airplane board, sand bag, and weights, are included when appropriate (Panelli and De Marco, 2009).

Several studies have evaluated the electromyographic (EMG) activity of the core muscles during Pilates exercises, both on the mat and the apparatus. Such exercises were reported as effective in strengthening the core muscles (Queiroz et al., 2010; Marques et al., 2013; Dias et al., 2014; Silva et al., 2015).

* Corresponding author. Department: Morphology (Anatomy), Institution: Piracicaba Dental School, UNICAMP, Brazil.
E-mail address: carol_panhan@hotmail.com (A.C. Panhan).

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The rectus abdominis muscle — the major flexor of the trunk (Norris, 1993) — plays an important role in spinal stability (Norwood et al., 2007). The internal oblique muscles — lateral flexors and rotators of the trunk — also contribute to spinal stability (Norwood et al., 2007), and, thus, are recruited during Pilates exercise (Rossi et al., 2014).

Some factors may increase the EMG activity of the paravertebral and flexor muscles during Pilates abdominal exercises. Among the factors is the use of unstable bases, such as a roller or a ball (Kim et al., 2011; Marshall and Murphy, 2003; Andrade et al., 2015).

While elaborating specific protocols aimed at training and/or rehabilitation, Pilates instructors should know what abdominal muscles are recruited and how active they are during Pilates exercise on different supporting bases. This might help them establish adequate exercise for all levels of training. Therefore, the present study aimed to analyze the effect of different trunk supporting bases on the EMG activity of the rectus abdominis (RA) and internal oblique (IO) muscles during the double leg stretch (DLS) exercise. Our hypothesis is that the smaller the trunk supporting base, the lower the trunk stability, resulting in a more intense activity of the RA and IO muscles during exercise.

2. Methods

2.1. Participants

Participants included sixteen right-handed women with a height and body weight of 1.64 ± 0.04 m and 58.7 ± 7.4 kg, respectively, and a mean age of 27.6 ± 3.7 years. They were randomly selected in two 'classic' Pilates studios, where they had been practicing for 4.1 ± 1.3 years, considering the following inclusion criteria: (a) women practicing Pilates for at least six months and having no musculoskeletal damage, (b) no pregnancy, and (c) no visually-identified asymmetries in the spinal trunk and lower limbs (Silva et al., 2015). This study was approved by the ethics and research committee of Piracicaba Dental School, University of Campinas (Unicamp): protocol 5418/2017.

2.2. Data recording

A direct transmission system (TELEmyo DTS, 16 channels, 1500 Hz), along with the software myoMUSCLE (Noraxon®, Scottsdale, AZ, USA), was used to capture the electromyographic biological signals. The software was set at a total gain of 2000 times (20 times for the sensor and 100 times for the equipment), with an analogue-digital converter resolution of 16 bits and an analogue bandpass filter (20–500 Hz). Ag/AgCl surface electrodes (Miotec®,Porto Alegre, Rio Grande do Sul, Brazil) were 10 mm in diameter. The root mean square (RMS) values obtained from the DLS exercise were normalized by the RMS values obtained during the maximal voluntary isometric contraction (MVIC) test measured with the isokinetic dynamometer (System 4 Pro, Biodex®, Shirley, New York, USA) during each exercise (Escamilla et al., 2010).

All experimental procedures were carried out at the Laboratory of Biomechanics (LABIOMEC), UNESP, Rio Claro, São Paulo, Brazil. For data collection, volunteers first did an active warm-up of their trunk muscles for approximately 2 min–40 s for alternate trunk rotation, 40 s for alternate trunk flexion, and 20 s for static stretching on each side — in a standing position.

After the warm-up, the electrode placement site was shaved and cleansed with 70% alcohol to reduce impedance. The electrodes were placed on the dominant side of each participant on both muscles: IO — 2 cm medially and inferiorly to the anterior superior iliac crest; and RA — 3 cm away from the midpoint of the midline — navel to xiphoid process (Marques et al., 2013).

All participants were tested for the MVIC of the trunk flexion in a sitting position (see Fig. 1). The shoulders, torso, and thighs of the participants were secured by straps, and the angle between the waist and thigh was fixed at 90° (Kliziene et al., 2016). They did a 5-sec warm-up prior to the test, which involved three 5-sec maximal flexion contractions, with 30-sec intervals between contractions (Gruther et al., 2009). They were instructed to carry out the contractions as fast and as strong as they could and were verbally stimulated during the test. The highest torque value of such contractions was established as the trunk flexion MVIC.

Fifteen minutes after the MVIC test, all participants did DLS exercises on three different supporting bases — mat ($120 \times 100 \times 5$ cm), long box ($90 \times 45 \times 55$ cm), and short box ($40 \times 20 \times 35$ cm) — with a 10-min interval (Silva et al., 2015). They were instructed to do eight repetitions of exercise for each base under the 50 bpm metronome rhythm, in accordance with standard protocols of the Pilates method (Pilates and Miller, 1945). The order of each exercise supporting base was established by drawing.

The DLS exercise, for all supporting bases (see Fig. 2), started in a supine position (neck flexion and trunk flexion), with their hip and knees flexed toward the chest and their hands below the patella, followed by extended upper and lower limbs, with their head, shoulders, arms, and legs off the supporting base. The exercise was done according to a protocol described by Silva et al. (2015) — inspiration was done during knee flexion and expiration during extended legs and arms.

EMG signals were analyzed using specific routines developed in Matlab software (version 2009, Natick, MA, United States) as they were filtered (4th-order Butterworth) at 20–500 Hz frequencies and processed in the time domain.

2.3. Data analysis

The BioEstat 5.3 software (version 2007, Belem, PA, Brazil) was used to analyze the data concerning all statistical tests. Data

Fig. 1. Trunk flexion test: MVIC values.

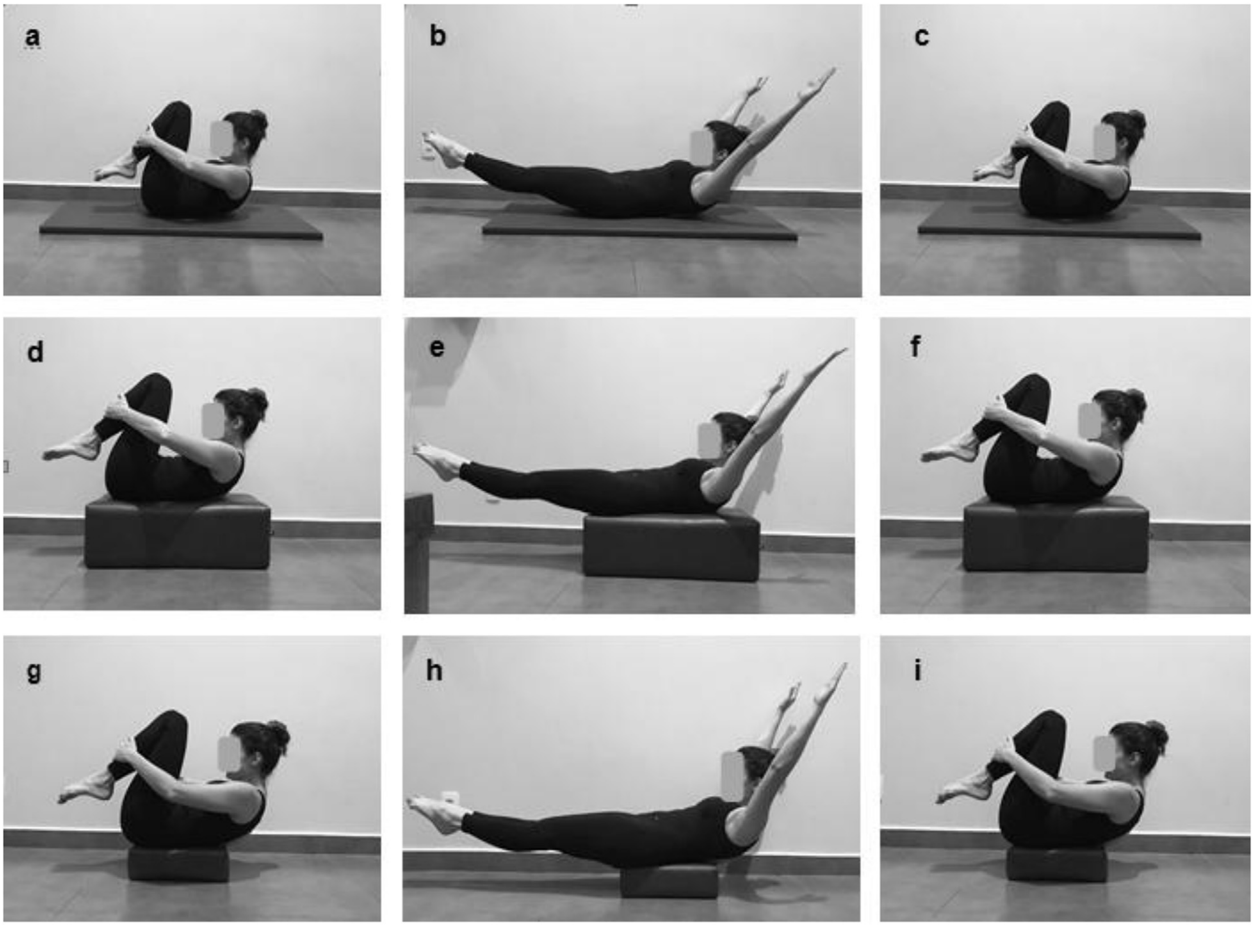

Fig. 2. Individuals' positions during exercise on the supporting bases: mat (a,b,c); long box (d,e,f); and short box (g,h,i).

normality was assessed by the D'Agostino test. One-way repeated-measured analysis of variance (ANOVA) was used to verify difference in muscle (RA and IO) activity among three supporting bases. The post-hoc Bonferroni test was applied when necessary. The Student *t*-test was used to verify difference in muscle activity concerning each supporting base separately. Statistical significance was set at $p < 0.05$ for all tests. Data were expressed as mean and standard deviation (SD).

3. Results

Fig. 3a (i and ii) shows the EMG values — expressed as percentage of maximal voluntary isometric contraction (%MVIC) — of the RA and IO muscles, which were assessed and compared among the three bases. The highest values concerning both muscles were observed for the exercise on the short box (84% and 92%, respectively), followed by the long box (66% and 71%) and the mat (55% and 57%). ANOVA and Bonferroni tests showed statistically different %MVIC values between the mat and short box, regarding RA ($p < 0.05$) and IO ($p < 0.05$).

Fig. 3b (i, ii and iii) shows a comparison between muscles for each supporting base. Statistical analysis (Student *t*-test; $p < 0.05$) showed no significant difference between the muscles, concerning exercise on the mat ($p = 0.9266$), on the long box ($p = 0.5113$) and on the short box ($p = 0.2972$).

Based on our results, all supporting bases showed intense activity of the muscles assessed. High intensity levels were detected for the mat and very high for the long and short boxes, with the latter showing the highest levels (Digiovine et al., 1992; Escamilla et al., 2010).

4. Discussion

The Pilates method has been recommended for therapeutic purposes or physical fitness in healthy individuals, aiming at some particular muscles. However, no studies have been found to investigate EMG of the RA and IO trunk muscles during Pilates exercise on supporting bases of different sizes. Our hypothesis was that the smaller the trunk supporting base, the lower the trunk stability, resulting in a more intense activity of the RA and IO muscles during exercise.

Since the RA and IO muscles are responsible for trunk stability, they are expected to be more recruited on a stable base (Behm and Colado, 2012). Although not targeted in the present study due to complexities involving EMG signal interference and difficulties in accessing it, the transversus abdominis muscle — which maintains the intra-abdominal pressure — is fundamental for trunk stability. The thoracolumbar fascia also has an important role; it is attached to the internal oblique and transverse abdominis muscles and thus provide three-dimensional support to the lumbar spine and aid in core muscle stability (Young et al., 1996).

Previous studies (Digiovine et al., 1992; Escamilla et al., 2010) have categorized the muscle activity EMG values (%MVIC) into four intensity levels: low (<21%), moderate (21–40%), high (41–60%), and very high (>60%). Levels of %MVIC greater than 45% are likely to induce muscle strengthening (Ekstrom et al., 2007). In the present

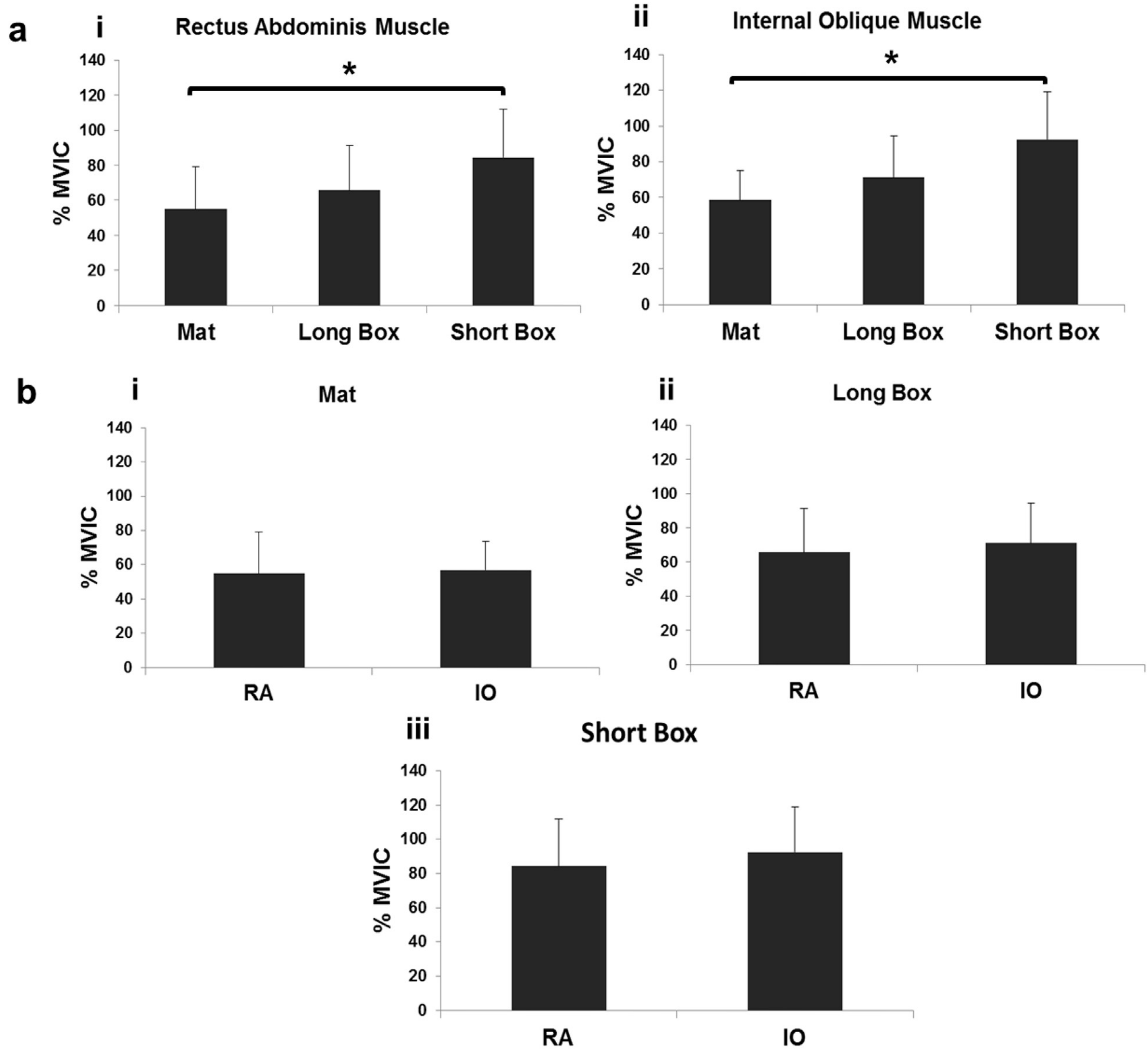

Fig. 3. a. MVIC values for (i) Rectus Abdominis and (ii) Internal Oblique considering the three supporting bases. Asterisk (*) represents $p < 0.05$. b. Differences in muscle activity among supporting bases: (i) mat; (ii) long box; and (iii) short box.

study, %MVIC values were greater than 45% for RA and IO during exercise on the three different supporting bases, suggesting that the targeted exercise can be used to strengthen the core abdominal muscles.

Trunk stability depends mostly on the intensity and the individual's positioning adopted for each exercise (Loss et al., 2010). In the present study, the exercise on the short box showed the highest MVIC values (Fig. 3a). This might be due to the smaller base resulting in a lower stability of the trunk, a condition in which the abdominal muscles, especially the RA and IO, are recruited to give more stability to the trunk.

Comparison between the two muscles considering each of the three supporting bases separately showed no statistical differences in muscle activity (Fig. 3b). The exercise applied was able to challenge the stability of the trunk and thus recruit its stabilizer (IO) and mobilizer muscles (RA) at the same intensity (Bergmark, 1989; Gibbons and Comerford, 2001; Cardozo and Gonçalves, 2006).

The abdominal muscles are responsible for trunk stability as they reduce the load on the spine during body movements; such muscles, if weak, might generate biomechanical disorders and pain in the back (Axler and McGill, 1997). While choosing the exercise to strengthen the abdominal muscles, the Pilates instructor should be aware that each abdominal muscle plays a particular role in stabilizing and mobilizing the spine (Comerford et al., 2011). Strengthening the core muscles is fundamental for stabilizing the spine and preserving its structures and the trunk functions (Rossi et al., 2014).

Our results showed that the muscle activity increased as the size of the base decreased; our findings might help Pilates instructors decide over the size of the trunk supporting bases, according to their students' levels — basic, intermediate or advanced. The trunk supporting base size could be reduced as the level advances.

4.1. Limitations

Although the sample size is deemed adequate for the present investigation, a larger number of Pilates exercises would result in a more substantial impact on our findings and allow the authors to investigate other muscles. Also, a comparison between practitioners and non-practitioners would help eliminate bias. Muscle activation might respond differently in non-practitioners (Ref).

5. Conclusion

The short box increased the activity of the rectus abdominis (RA) and internal oblique (IO) muscles during the Pilates exercise assessed. EMG values (%MVIC) concerning both muscles were statistically different among the bases. The more unstable the supporting bases of the trunk, the more its mobilizer (RA) and stabilizer (IO) muscles were recruited.

5.1. Practical application

- The results of this study provide Pilates instructors with information on the EMG characterization of double leg stretch exercise on trunk supporting bases of different sizes.
- EMG analysis can be used to establish Pilates exercise levels.
- Further studies involving individuals with different clinical conditions and other muscle groups and types of exercise are needed to confirm our findings and develop protocols aimed at Pilates exercises for specific purposes.

Conflicts of interest

None.

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This research project was approved by the ethics committee of Piracicaba Dental School; protocol: 5418/2017.

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