THE IMMEDIATE EFFECTS OF TWO PILATES EXERCISES WITH AND WITHOUT A FOAM ROLLER ON ABDOMINAL MUSCLE ACTIVITY

Ariany Klein Tahara1 , Érica Engrácia Valenti[1], Fuengfa Khobkhun[2],*, Jim Richards[3],*, Paulo Roberto Pereira Santiago4, *

[1]Ribeirão Preto Medical School, University of São Paulo, Ribeirão Preto, Brazil; arianytahara@usp.br
[2]Faculty of Physical Therapy, Mahidol University, Nakhon Pathom, Thailand; fuengfa.kho@mahidol.edu
[3]Allied Health Research Unit, University of Central Lancashire, Preston PR1 2HE, UK; JRichards@uclan.ac.uk
[4]School of Physical Education and Sports of Ribeirão Preto, University of São Paulo, Ribeirão Preto, Brazil; paulosantiago@usp.br

*Correspondence: paulosantiago@usp.br

Abstract: Pilates can be defined as exercises which are floor-based or use specialized equipment to provide resistance. The use of foam rollers (FR) have been purported to improve the recruitment of core muscles by creating an unstable surface, providing improvements to balance, posture and functional recovery in daily activities. However, there is a paucity of studies exploring the use of FR as an unstable surface. The aim of this study was to analyze the acute effects on the recruitment of core muscles during two Pilates exercises, a single leg stretch (SL) and single straight leg stretch (SS), on the ground and using a FR as an unstable surface. Thirty women aged between 25 to 35 years old who had not previously practiced Pilates participated in this study. Surface EMG signals were collected from rectus abdominis (RA) and external oblique (EO) muscles during an isometric contraction lasting 30 seconds during the exercises. Two-factor Repeated Measures ANOVA tests with post hoc pairwise comparisons were used to investigate the muscle activity between the two stretching exercises when performed on the ground and using the FR. No significant interaction effects were seen between the two exercises and positions, and no main effects were seen for either factor. These findings do not indicate the influence of the surface (ground versus FR) or exercise (SL versus SS) on the muscle activity of the rectus abdominis and external oblique muscles when considering the immediate effects. Future studies should consider the effects over a longer time period.
Keywords: Biomechanics; abdominal muscle activity; surface electromyography; foam roller; Pilates

1. **Introduction**

Pilates can be defined as exercises which are either floor-based or use specialized equipment to provide resistance (Wells et at 2012). The focus of such methods is to increase muscle recruitment and the strengthening of the core muscles, flexibility, and breathing, promoting stability and control of movement (Alves et al 2020). In addition, Pilates can be practiced by young and older adults alike and people with musculoskeletal conditions and has been shown to have a positive impact on pain, function, and quality of life in those who practice it (Gibbons & Bird 2019). Pilates can be used in conjunction with equipment, for example, Swiss balls or foam rollers (FR), which have been purported to improve the recruitment of muscles of the trunk and abdomen by creating an unstable surface or during single-limb stance exercises to increase core muscle activity (Di Lorenzo 2011). The activation of core muscles has been shown to help to stabilize the spine, improve balance, posture, body awareness, pain avoidance, and has been shown to provide improvements in function during activities of daily living (Gibbons & Bird 2019, Lee et al 2021).

The use of FRs by athletes for training and non-athletes for rehabilitation has grown in popularity in recent years (Junker & Stöggl 2019) and is commonly used to improve range of motion (ROM) (Konrad et al 2021), prevent injury and help with recovery (Hendricks et al 2020), and improve muscle performance and flexibility (Wiewelhove et al 2019). It has been reported that FR can be used to release myofascial pain and reduce the onset of muscle soreness (Hendricks et al 2020). Most of the studies using FR have reported their use on the acute effects of stretching, for example, comparing dynamic and static stretching activities (Junker & Stöggl 2019, Konrad et al 2021, Hendricks et al 2020, Wiewelhove et al 2019). However, there is a paucity of studies exploring the use of FR as an unstable surface with the view to improve the recruitment of core muscles and strength training (Pereira et al 2017) during Pilates exercises. Moreover, there is little or no data comparing the effect of different Pilates exercises on muscle activity.

A decrease of stability using different surfaces has shown that individuals with low back pain have less activation of the abdominal muscles when compared to healthy individuals using ultrasound (Rasouli et al,2020). In addition, Gala-Alarcón et al, (2018) used ultrasound to measure the muscles after one-year of practicing Pilates and showed a decrease of thickness of rectus abdominis that it is connected to an improvement in the stability of the lumbar region. There has been a focus on the evaluation of abdominal wall muscles using ultrasound, as well as deeper muscles such as transversus abdominis and the internal oblique, however this assessment is difficult to perform during the exercises themselves. EMG has been used to evaluate trunk muscle activity during Pilates exercises with a focus on the stabilizers and deeper abdominal muscles (Kim & Lee 2017) who concluded that a Pilates breathing exercise increased the activity of these deeper muscles, as well as the stabilization of the trunk, however little work exists exploring the effects on the more superficial abdominal muscles which could provide useful insights into the efficacy of Pilates exercises. Therefore, the aim of this study was to explore the use of Pilates exercises using the FR to provide an unstable surface to determine any changes in the recruitment of superficial abdominal muscles measured by surface electromyography. We hypothesized that the Pilates exercise with FR as an unstable surface would have an immediate effect on rectus abdominis (RA) and external oblique (EO).

2. **Methods**

2.1. **Participants**

Recruitment was conducted by placing posters within the community setting including local shops, athletic clubs and community centers. The inclusion criteria were women aged 25 to 35 years old who had not previously practiced Pilates, were independent in activities of daily living, in good physical health, non-smokers, were able to understand and execute breathing patterns used in Pilates, and able to maintain abdominal contractions typical of Pilates exercises. Participants were excluded if they reported labyrinthitis, or had any current cardiorespiratory, neurological or musculoskeletal conditions that could compromise their performance of the Pilates exercises. The sample size was determined based on previous studies using Pilates exercises (Silva et al 2015, Kawana et al 2022, Lee K. 2021) which indicated that 30 participants were required. This study was approved by the Ethics Committee in Research of the Faculty of Sciences of the São Paulo State University, Marília-SP, (Protocol No. 186 059) and followed the resolution 196/96 Brazil's National Health 10/10/1996. All participants read the participant's information sheet and signed the consent form before taking part in the study in line with the Declaration of Helsinki.

2.2 **Assessments**

Participants were asked to wear comfortable exercises clothes that did not limit their movement. Four Trigno bipolar electrodes (Delsys Inc., USA) were positioned over the left and right rectus abdominis (RA) and external oblique (EO) muscles (Park et al 2013) according to the SENIAM recommendations (SENIAM 2012, Hermes et al 2000) (Figure 1). Prior to placing the electrodes, the skin was cleaned with a 70% alcohol solution.

Insert Figure 1 here.

Data were recorded at a sampling frequency of 2000 Hz during a 30-seconds isometric contraction during two Pilates positions which were performed with and without the FR. Exercise 1 was a single leg stretch (SL) that consisted of the individual being in a supine position with the head and thoracic spine elevated and the forearms on the floor, with the right lower limb flexed towards the trunk and left lower limb extended, with the individual alternating the position of the lower limbs (Figure 2, A and B). Exercise 2 was a single straight leg stretch (SS) in dorsal decubitus, with the head and thoracic spine elevated, right lower extended, hip flexed, left lower limb at 45° from the ground, and forearms supporting on the floor, with the individual alternating the position of the lower limbs (Figure 2, C and D). Five repetitions were performed for each leg along with breathing control according to the Pilates fundamentals of inhalation and exhalation during the movement (Andrade et al., 2015, Escamilla et al.,2015). Five minutes of rest was allowed between each exercise.

Insert Figure 2 here.

These exercises focused on the Pilates principles of centering, concentration, control, precision, flow and breathing (Wells et al., 2012). All exercises were explained and supervised by a pilates instructor and were selected based on previous research that demonstrated their effectiveness in targeting the specific muscle groups and movements involved in the study. The SL and SS exercises were chosen as they characterised movements involving gross motor coordination, breathing, activation of the abdominal muscles, as well as activating the hip flexors, and muscles of the upper and lower limbs (Pilates & Miller, 1998). These are exercises commonly used to recruit and strengthen the abdominal muscles, and are easily performed, even by people who have never practiced Pilates before. Even though these exercises are common among Pilates practitioners, little data exists evaluating the muscle activity during these exercises and the effect of performing these using stable and unstable surfaces. This may inform their use when managing individuals affected by injury (Loss et al, 2010).

2.3 Data processing

The analysis of the EMG data was carried out using MATLAB 2012b. A remove mean was applied to the raw EMG signals to correct for any baseline offsets. A Butterworth bandpass filter 10 Hz to 450 Hz was used to eliminate low-frequency noise from the sEMG signal. The data were then full wave rectified and low-pass filtered using a cutoff frequency of 10 Hz. To restrict the analysis to periods of muscle activation, muscle activity onset and offset events were identified using the rectified data. The peak EMG signal of the ensemble average of the five repetitions were normalized to the maximum observed EMG signal from all trials for each volunteer, and data between the onset and offset events were exported for statistical analysis.

2.4 Statistical Analysis

For statistical analysis, SPSS statistics version 24 (IBM Corporation, Armonk, NY) was used to analyze the data. The distribution of the data was verified using the Shapiro-Wilk test, and all data were found suitable for parametric analysis. Therefore, a 2 x 2 repeated measures analysis of variance (RM ANOVA) was performed on EMG data with the factors being; surface (ground vs. FR) and exercise (SL vs. SS), and the significance level was set to $p < 0.05$.

3. Results

Thirty women with a mean ± SD age of 28.8 ± 2.5 years, the weight of 58.8 ± 7.4 kilograms, and height of 1.60 ± 4.0 meters participated in the study. The RM ANOVA found no significant interactions and no main effects for peak enveloped EMG values between surface (ground vs. foam roller) or exercise (Single leg stretch vs. Single straight leg stretch) exercises.

Insert Table 1 here.

4. **Discussion**

The purpose of the present study was to analyze and compare the immediate effects on the activity of the core muscles as a result of the two Pilates exercises when performed with and without a foam roller. There were no significant main effects between the exercises or with and without foam roller. Our results differ from a study that compared the amplitude of EMG activity of rectus abdominis, abdominal external oblique, transversus abdominis and internal oblique during a single-legged hold exercise performed on the floor and on a round foam roller (Kim et al 2011). In the previous study, the exercise performed using the FR had greater activation of abdominal muscles than on the ground; and also there were different levels of muscle recruitment on the left and rights sides while on the unstable surface, with the transversus abdominis/internal oblique muscles showing greater activation on the contralateral side, whereas RA and EO were more activated on the same side of the movement (Kim et al 2011). We analyzed only RA and EO muscles in two different positions, and did not consider trunk rotation during the movement, focusing only on superficial abdominal muscles, which might explain the difference in response. In our study we also asked the volunteers to keep their head and shoulders off the surface and roller when performing the exercises, which may create additional effort within the trunk muscles to hold the position and may have masked any differences in the muscle activation of RA and EO between the tasks.

Another study that used the FR as an unstable surface considered the thickness of transversus abdominis internal and external obliques. In this study, the authors compared a Pilates table as a stable surface and two unstable surfaces; Oov and FR during isometric exercises and used ultrasound to assess the muscle thickness (Gibbons & Bird 2019). The results showed that the unstable surfaces, specifically FR elicited more muscle thickness. Our study differs from this work as we did not assess the deeper abdominal muscles and we used sEMG to determine the levels of activity within RA and EO.

Concerning unstable surfaces and muscle activity using EMG, Escamilla et al., 2015 used a Swiss Ball to compare the activation of abdominal and trunk muscles in different positions. This study focused on muscle activity during prone, supine, and side positions to determine which produces the greatest activation of the muscles within the abdomen and trunk (Escamilla et al 2015). In our study, we focused on RA and EO in a supine position during an isometric contraction, a process that would be easier to be performed by novices to Pilates exercises. Escamilla et al were able to differentiate between positions which may be due to the degree of difficulty or type of exercise, however the results showed that muscle activity was similar in all or most of the core muscles when exercising in supine positions, with the greatest activity being seen when subjects were in a prone position using the ball, which was also reported to be the most difficult exercise to perform (Escamilla et al 2015).

Lee (2021) analyzed the biomechanical relationship between trunk activation and the stability of the core muscles using EMG. The results showed that deep abdominal muscles (internal oblique) were more activated than RA, and differences in subjects who practiced Pilates activated core muscles and had better stability than those who had not practiced Pilates before (Lee 2021). Most of the studies exploring the effect of Pilates on abdominal muscles have a focus on deeper muscles (Gibbons & Bird 2019, Kim et al 2011, Escamilla et al 2015, Moon et al 2015, Kang et al 2017, Cho & Jeon 2013) or RA and EO in association with trunk muscles (Park et al 2015, Calatayud et al 2019, Lee et al 2016, Tahan et al 2016), or the use of other tools to assess, such as ultrasound to measure muscle thickness (Gibbons & Bird 2019, Moon et al 2015, Cho & Jeon 2013, Tahan et al 2016) or other unstable surfaces (Escamilla et al 2015, Feldwieser et al 2012, Lee et al 2016). Pereira et al. (2017) reported that RA and EO were more activated during the single-leg stretch exercise compared to other Pilates positions, and this change in activation occurred within the first session of Pilates (Pereira et al 2017). This variety of approaches to analyse the superficial abdominal muscles on unstable surfaces during exercises may be responsible for the different results.

According to Joyce and Kotlher (2017), the definition of spine stability is the ability to maintain a neutral position during static or dynamic tasks which is achieved by a complex interaction of structures, including muscles. These authors cited the transversus abdominis muscles as the main spine stabilizers but did not exclude the role of RA and OE. Pilates improved RA force, lumbopelvic stability, and abdominal endurance and also eliminated asymmetries of OE (Joyce & Kotlher 2017). The systematic review by Hendricks et al. (2019) analysed the application of FR during warm-up to improve the performance and during the warm-down recovery stage (Hendricks et al 2019). This showed that the use of FR as an unstable device can increase the activation of core muscles. A recent study by Kim and Lee (2021) compared the activation of core muscles during a specific Pilates exercise in two different knee joint angles (90° and 180°) and using two different props, the soft ball mini and the Pilates ring. The sample was with men who had at least three months of Pilates practice. This study used EMG in the same superficial abdominal muscles as in the current study, plus rectus femoris, vastus medialis and lateralis, biceps femoris and semitendinosus. The authors observed an increase in core muscle activity (Kim & Lee 2021). Explanations for the differences with this current study could include, the nature of the tasks chosen and the selection of individuals who had not previously practiced Pilates.

Breathing is very important during Pilates exercises. During the exhalation, abdominal muscles are prone to be more activated and they tend to contract isometrically, contrary to the passive characteristic pattern of expiration. In this way there is increased abdominal pressure, which assists in stabilizing the trunk and can produce better muscle activation, as well as improved stability (Kim & Lee 2017). In our study, the participants learned the Pilates breathing and were encouraged to apply it while executing the exercises, but the results could differ because they had no prior Pilates experience, which includes breathing in a correct way plus the fact of moving over an unstable surface, the foam roller.

There are several limitations in this study. Firstly, this study evaluated a small convenience sample, so the findings may not be generalizable to other groups or Pilates exercises. As this was an exploratory study we did not calculate the sample size, but the sample size chosen was similar to previous studies considering Pilates exercises. Second, therapeutic effects such as the reduction of lower back pain or the gain of muscle stretching were neither measured nor evaluated in the exercises. Lastly, the study analyzed the immediate effects of muscle recruitment, and future studies should also consider exploring the effects over a longer time period and the development and exploration of specific programs for training the abdominal region using the foam roller with a greater consideration of the stabilization of the lumbar spine.

5. **Conclusions**

We expected to find greater muscle activity when performing Pilates exercises when using the foam roller as an unstable surface, but our results did not show a significant difference between the exercises or between the use of FR and ground.

6. Clinical Relevance

There was no significant difference in muscle activity during two Pilates exercises when the foam roller was used as an unstable surface. There were no immediate effects concerning rectus abdominis or external oblique muscles.

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TABLE 1

Surface	Exercise	Peak enveloped EMG values (n = 30)			
		rRA	lRA	rOE	lOE
Groud	Single leg strech	47.5±7.3	49.1±7.8	45.7±12.1	45.0±8.9
	Single straight leg stretch	51.0±13.6	45.3±12.8	41.8±12.2	43.6±11.9
Foam roller	Single leg strech	45.3±9.8	45.7±11.5	40.1±12.5	45.4±8.7
	Single straight	45.7±12.4	48.5±8.6	44.0±12.7	44.4±8.8

	leg stretch				
Ground versus Foam roller P-value and effect size (pn²)		0.06 (xx)	0.98 (xx)	0.45 (xx)	0.71 (xx)
Single leg stretch versus Single straight leg stretch p-value and effect size (pn²)		0.35 (xx)	0.79 (xx)	0.99 (xx)	0.49 (xx)
Interaction between factors p-value and effect size (pn²)		0.44 (xx)	0.09 (xx)	0.08 (xx)	0.92 (xx)

Table 1. Peak enveloped EMG values (mean ± standard deviations) for both conditions (ground and foam roller) in both types of exercises (single leg stretch e single leg straight) for right rectus abdominis (rRA), left rectus abdominis (lRA), and right abdominal external oblique (rEO) and left abdominal external oblique (lEO), n=30.

FIGURE 1

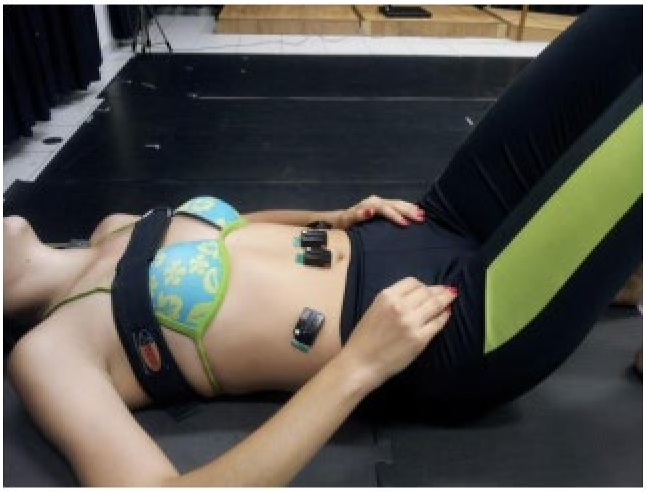

Figure 1: Position of the electrodes on the volunteers' abdomen.

FIGURE 2

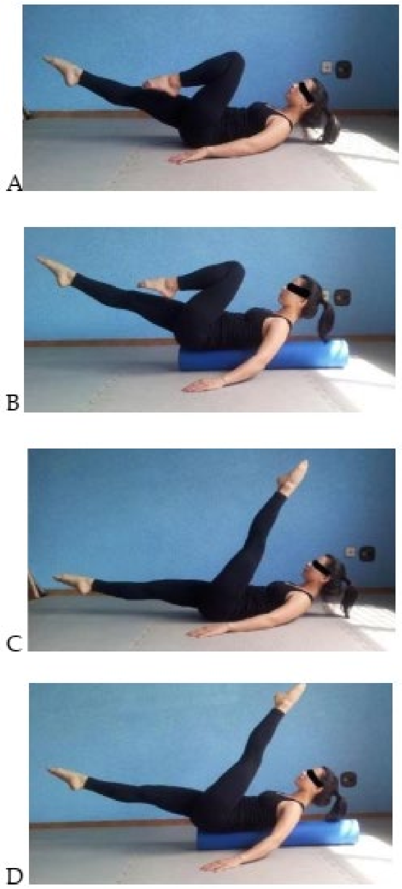

Figure 2. (A) Single leg stretch on the ground (B) Single leg stretch using the foam roller (C) Single straight leg stretch on the ground (D) Single straight leg stretch using the foam roller.