Application of Pilates principles increases paraspinal muscle activation

Leticia Souza Andrade, PT a,*, Luís Mochizuki, PhD b, Flávio Oliveira Pires, PhD b, Renato André Sousa da Silva, MsC c, Yomara Lima Mota, PhD a

a Department of Physical Education and Physiotherapy, Catholic University of Brasilia, Brazil
b School of Arts, Sciences and Humanities, University of São Paulo, Brazil
c Department of Physical Education, Catholic University of Brasilia, Brazil

Received 22 June 2014; received in revised form 20 October 2014; accepted 11 November 2014

Summary  Objective: To analyze the effect of Pilates principles on the EMG activity of abdominal and paraspinal muscles on stable and unstable surfaces.
Methods: Surface EMG data about the rectus abdominis (RA), iliocostalis (IL) and lumbar multifidus (MU) of 19 participants were collected while performing three repetitions of a crunch exercise in the following conditions: 1) with no Pilates technique and stable surface (nP+S); 2) with no Pilates technique and unstable surface (nP+U); 3) with Pilates technique and stable surface (P+S); 4) with Pilates and unstable surface (P+U). The EMG Fanalysis was conducted using a custom-made Matlab® 10.
Results: There was no condition effect in the RA iEMG with stable and unstable surfaces ($F_{(1,290)} = 0.98$) and with and without principles ($F_{(1,290)} = 1.26 p = 0.27$). IL iEMG was higher for the stable surface condition ($F_{(1,290)} = 32.3 p < 0.001$) with Pilates principles ($F_{(1,290)} = 21.9 p < 0.001$). The MU iEMG was higher for the stable surface condition with and without Pilates principles ($F_{(1,290)} = 84.9 p < 0.001$).
© 2014 Elsevier Ltd. All rights reserved.

Introduction

In 1920, Joseph Pilates (1880–1967) created a specific exercise method that was intended for rehabilitating soldiers injured during World War I. This exercise technique, the Pilates method, was based on a continuing focus on body awareness so that the self-perception of the body and kinesthesia would be improved during exercise. It has been suggested that this kind of approach during exercise might...
lead to a self-body awareness that would connect mind and body (Wells and Kolt, 2012; Latey, 2001).

Pilates-based exercises have been used for low back pain prevention or rehabilitation as this kind of conditioning exercise may activate the deep trunk muscles, providing greater spine stability (Muscolino and Cipriani, 2004). The current literature supports the notion that reductions in chronic low back pain after a bout of Pilates-based exercises may be obtained through improvements in postural control due to an increased muscular endurance strength and flexibility (Rydeard et al., 2006; Lim et al., 2011; Newell et al., 2012; Sekendiz et al., 2007; Kaesler et al., 2007).

Pilates practitioners believe that such an increased muscular endurance strength and flexibility and improved postural control may be a consequence of principles that include mental concentration, control, centering, flow, precision and breathing (Latey, 2001; Muscolino and Cipriani, 2004). For example, while centering increases spinal stability promoted by the co-contraction of antagonist muscles (Marques et al., 2012), controlling the forced expiration during the movement may recruit abdominal muscles (Neumann and Gill, 2002) and increase the activity of the lumbar-pelvic stabilizer muscles (Santos et al., 2010). Furthermore, combining self-control and centering may increase the biceps brachial activity and the electromyography (EMG) of co-activated muscles such as the multifidus, iliocostalis lumborum, rectus abdominis and internal oblique muscles (Rossi et al., 2013; Barbosa et al., 2013).

However, an important methodological aspect regarding Pilates studies (Marques et al., 2012; Neumann and Gill, 2002; Santos et al., 2010; Rossi et al., 2013; Barbosa et al., 2013) precludes a consistent understanding of the Pilates principles, as most studies have not included all the principles together when investigating Pilates-based exercises. Therefore, it is not possible to know whether positive effects on rehabilitation and physical fitness after a Pilates-based exercises program could be obtained without the application of the principles. In theory, it is necessary to include mental concentration, control, centering, flow, precision and breathing when evaluating the Pilates method’s effectiveness (Di Lorenzo, 2011).

In contrast, a concurrent Pilates-based method suggested for rehabilitation purposes is the proprioceptive method. This method uses unstable surfaces such as a foam roller or gym ball to improve proprioceptive mechanisms, which are believed to be important for the effectiveness of rehabilitation during the Pilates program. For example, studies have suggested the effectiveness of using unstable surfaces and reported increases in the activation of abdominal and paravertebral muscles during crunch, pushup and single-legged hold exercises (Vera-Garcia et al., 2000; Kim et al., 2011; Marshall and Murphy, 2005; Escamilla et al., 2010; Sternlicht et al., 2007).

Therefore, the aim of this study was to investigate the effects of using Pilates principles on the electromyography activity of abdominal and paraspinal muscles during a crunch exercise on to the ground and using the foam roller. Due to controversial results, two hypotheses were formulated: There is a difference in the EMG activity of the rectus abdominis, iliocostalis and lumbar multifidus when the crunch exercise is done under a stable condition compared to when it is done under an unstable condition.

Materials and methods

Participants

Nineteen healthy women (25.6 ± 5 years old, body mass of 52 ± 6 kg, height of 162 ± 0.1 cm, and body mass index of 19.7 ± 2 kg/m²), not experienced with Pilates exercise, volunteered to take part in this crossover study. They were recruited from the university campus according to the following inclusion criteria: 1) absence of acute or chronic low back injury or prolonged back pain; 2) negative diagnosis of orthopedic, rheumatologic, neurologic and respiratory disorders; 3) absence of congenital or acquired anomalies in upper and lower limbs. After explaining the risks and benefits of the experimental procedures, participants signed a written informed consent. All the procedures were previously approved by the local Ethics Committee (15212313.3.0000.0029) and conducted in accordance with the Helsinki declaration.

Procedures and instruments

A 16-bit, four-channel surface electromyography system (EMGSystem®, 630C Brazil) measured the muscle activity at a sampling rate of 1 kHz, while the EMG signal was recorded by a specific software (EMGlab, EMGSystem®, Brazil). After skin exfoliation and cleaning (70% isopropyl alcohol), bipolar surface Ag/AgCl electrodes (Kendall-Meditrace 200®) were placed over the rectus abdominis (RA), iliocostalis (IL) and lumbar multifidus (MU) muscles, following the probable muscle fiber orientation. Electrodes were placed within a 4 cm inter-electrode distance and fixed by adhesive tape parallel to the muscle fibers. In order to ensure a reliable localization, the electrodes were placed according to the SENIAM (surface electromyography for the noninvasive assessment of muscles) according to the following description (Hermens et al., 2000): IL muscle, 6 cm lateral to the intervertebral space L2–L3; MU muscle, 2 cm lateral to the midline of the interspinous space L4–L5; and the principal muscle responsible for flexion of the trunk, the RA muscle, 2 cm lateral to the umbilicus.

Exercise protocol

Three repetitions of a crunch exercise were performed in four different conditions: 1) no Pilates technique and stable surface (nP + S); 2) no Pilates technique and unstable surface (nP + U); 3) Pilates technique and stable surface (P + S); 4) Pilates technique and unstable surface (P + U). A foam roller was used as an unstable surface and the exercises were performed in sequential order to avoid any influence from prior knowledge of the Pilates principles. The participants were familiarized with the crunch exercise execution according to the Pilates principles (mental
concentration, self-control and centering, flow, precision and breathing). Before the familiarization they were informed about the Pilates-based exercises regarding the pelvic position (neutral), thoracic cage position, breathing, movement and stabilization of the shoulder girdle, head and cervical spine position and pelvic floor activation. These techniques, referring to the modern Pilates principles, have been used to improve posture and control of movement.

During the movement execution, participants were instructed to maintain the pelvis in a neutral position. A pressure biofeedback cuff unit (Stabilizer) was used to assist them in maintaining a neutral position with a neutral pelvis during the exercise. The pressure cuff unit was placed under their lumbar spine and inflated up to 20 and 40 mmHg. The participants were instructed to maintain the neutral position by maintaining a target pressure, visually controlled on an analog pressure gauge during the trunk flexion. In all situations it was emphasized that volunteers should maintain a neutral lumbar spine to avoid pressure on the electrodes from the paraspinal muscles. The execution of the crunch exercise using the foam roller promoted greater pressure in the cuff unit due to the smaller contact area compared to the ground.

Regarding the crunch exercises without applying all the Pilates principles, participants were instructed to keep their arms straight along the body while flexing the knees and maintaining the feet in a flat position, on stable and unstable surfaces. In contrast, crunch exercises while applying Pilates principles were performed on stable and unstable surfaces while participants kept neutral spine and pelvis positions, feet flat on the floor, and legs abducted at the hip line. Furthermore, they were recommended to keep the neck stretched to create a cranial-vertebral flexion during the inspiration phase. In addition, they were recommended to use pursed-lip breathing and contract the abdominal muscles during the expiration (Fig. 1).

Two footswitches connected to the EMG system were used to monitor the start and the end of the trunk flexion during the exercise (at the occipital region and at the vertebral spinous process at T7). The first footswitch indicated the start of the movement and the second footswitch indicated the end of trunk flexion.

Data analysis and statistics

The EMG analysis was conducted using a custom-made Matlab 10. The raw EMG signal was low-pass filtered (Butterworth 4th order, 200 Hz, demeaned and full-wave rectified to calculate the area under the EMG curve (iEMG) of the RA, IL and MU muscle activity. The iEMG was calculated at a time window of 200 ms in the middle of the crunch movement. Thus, the EMG data were normalized by the peak activation obtained during the crunch exercise.

Data were reported as mean and standard deviation (±SD). The two-way analysis of variance (ANOVA) and the post hoc Tukey test were carried out to evaluate the effect of the Pilates principles (with x without) and the variable surface (stable x unstable). The statistical significance was set when \( p < 0.05 \).

Results

Values of the RA, IL and MU muscle iEMG during exercise while using Pilates principles (with x without) and the variable surface (stable x unstable) are presented in Fig. 2. No variable surface effect was observed in the RA iEMG, comparing stable and unstable surface \( (F_{1,290} = 0, p = 0.98) \). Similarly, the conditions with and without Pilates principles did not affect the RA iEMG \( (F_{1,290} = 1.2, p = 0.27) \).

In contrast, IL muscle iEMG was affected by variable surface; an unstable surface produced lower iEMG than a stable one \( (F_{1,290} = 32.3, p < 0.001) \). Furthermore, the Pilates principles produced greater iEMG than in condition

Figure 1 Concentric phase of the abdominal exercise with pressure biofeedback cuff unit under lumbar spine: A) stable surface (S) and B) unstable surface (U).

Figure 2 Mean iEMG of rectus abdominis (RA), iliocostalis (IL) and lumbar multifidus (MU) muscles in the four different situations: stable (S), unstable (U), without principles (nP), with principles (P). + Comparison S and U, without P and P \( (p < 0.001) \) ++ Comparison S and U \( (p < 0.001) \).
without Pilates principles ($F_{(1,290)} = 21.9 \ p < 0.001$). A surface interaction effect in line with Pilates principles was observed so that the IL muscle iEMG was higher when the crunch exercise was performed on a stable surface while using the principles.

The MU muscle iEMG was further affected by the variable surface: the MU iEMG was higher on a stable surface than on an unstable surface ($F_{(1,290)} = 84.9 \ p < 0.001$). Fig. 2 shows these results.

**Discussion**

The aim of this study was to analyze whether the Pilates principles and the variable surfaces (stable and unstable) might affect abdominal and paraspinal muscle activation when a crunch exercise was performed. It was found that the Pilates principles did not maximize the EMG amplitude of the rectus abdominal muscles during the crunch exercise.

The results of the present study showed that activation of the RA muscle was not influenced either by trunk instability or the Pilates principles. Thus the application of the Pilates principles, such as centering, breathing and neutral pelvis, were not able to increase the RA muscle activation while performing a crunch exercise. Some authors have documented the potential of Pilates principles for specific muscular recruitment patterns. For example, Santos et al. (2010) observed different muscle activation patterns related to breathing technique in Pilates exercises, so that a greater RA and external oblique muscle activation occurred while performing a roll-up exercise (Kloubec, 2011; Suzuki et al., 1995). Important instead of investigating the combination of all Pilates principles, those authors investigated only the breathing principle.

In the present study, the use of a round foam roller did not change the abdominal muscle activation. Perhaps the legs and feet positions may not have allowed the foam roller movement as studies have shown that the performance of an abdominal exercise on an unstable surface, such as on a roller or a ball, increases the muscle activation due to a smaller contact area, which impairs the balance and trunk stability (Vera-Garcia et al., 2000; Kim et al., 2011; Marshall and Murphy, 2005). In this study, all volunteers were placed in the same position.

The highest MU iEMG was found when the trunk was stable, regardless of the Pilates principles. Escamilla et al. (2010) observed lower activation of the lumbar paraspinal muscle during abdominal exercises on a ball. Those authors emphasized that the low activation using a ball may have also developed muscle resistance. The highest MU activity observed in our study can provide mechanical stability to the lumbar spine, as the trunk flexor and extensor muscles are activated during the crunch exercise. Thus, a stable position is ensured with a balanced co-contraction (abdominal and paravertebral) providing stability of the lumbar spine and decreasing the load on the spine (Ebenbichler et al., 2001; Hodges and Richardson, 1996; Cholewicki et al., 1997).

Our results also suggest that the Pilates principles may be used to increase the IL contraction necessary to stabilize the lower back, suggesting its use for therapeutic proposals. Perhaps the neutral pelvis during the exercise influenced the IL activation. As a result, for the maintenance of a neutral pelvis the shear forces on the spine may have been reduced, leading to a reduced flexion position. The posterior pelvic tilt changes and high levels of lumbar flexion have been associated with increased load on the annulus and posterior ligaments of the spine (Gallagher et al., 2005; Mawston and Boocock, 2012). Accordingly, maintaining a neutral pelvis has been recommended during Pilates exercises.

Treatments for low back pain routinely include different types of “back exercise” such as spinal flexion exercises with differentiated postures. However, which type of exercise will provide a safe and effective treatment remains contradictory. For example, in treating patients with chronic mechanical low back pain, Elnaggar et al. (1991) compared the effects of spinal flexion and extension exercises on the severity of the low back pain and thoracolumbar spinal mobility. The results did not indicate whether a specific type of exercise may be more worthwhile than others in increasing the coronal and transverse mobility of the thoracolumbar spine. Thus, it may be suggested that either spinal flexion or extension exercises could be used to reduce the severity of chronic mechanical low back pain. Similarly, Dettori et al. (1995) compared two types of exercise and observed that flexion or extension exercises were more effective for treating patients with acute low back pain. Thus, together with previous results, the present study may suggest the effectiveness of crunch exercises with and without Pilates principles, regardless of the stability of the lumbar spine.

Some limitations of the present study should be highlighted. The RA, IL and MU muscles were analyzed unilaterally, and eventual lateral differences in electrical activation were ignored. Moreover, our results should be related only to the mat Pilates exercises. The present study acknowledges that future studies are required to enable better understanding of the effects of the Pilates principles among different exercises, populations and ages.

**Conclusions**

The RA muscle EMG was not affected by either the Pilates method or the use of a foam roller. The IL muscle EMG was higher on the stable surface and for the Pilates principle condition. The MU muscle EMG showed the highest activation in the stable surface condition. The therapeutic use of crunch exercises with Pilates principles should be chosen to achieve greater IL co-contraction to stabilize the lower back. Based on the results, it can be recommended that exercises are performed on a stable surface to maximize paraspinal activation.

**References**


