Objective: The purpose of this study was to examine back muscle activity during 3 traditional mat Pilates exercises. 

Methods: Eleven healthy female volunteers, aged between 18 and 30 years, participated in this cross-sectional study. Surface electromyography (sEMG) of lumbar extensor muscles was recorded simultaneously with kinematics data to identify the phases of movement. Three mat Pilates back exercises were compared: (1) swimming, (2) single leg kick with static prone back extension, and (3) double leg kick. Root mean square values of each muscle were recorded with 2 pairs of surface electrodes placed bilaterally on one lumbar extensor muscle (at L5). During phases of each exercise, sEMG signals were identified by video analysis. Electrical muscle activation was normalized by the maximal voluntary isometric contraction and used to compare back muscle activity among exercises. A 2-way repeated measures analysis of variance was performed to assess the differences in activation level during the exercises.

Results: The value of electrical muscle activity in the lumbar extensors ranged between 15% and 61% of MIVC for the 3 types of Pilates mat work exercise. The swimming exercise increased lumbar extensor activity (29% on average) in comparison to the other 2 Pilates conditions. Interestingly, the double leg kick exercise generated significantly more lumbar extensor activity (26% on average) than the single leg kick.

Conclusions: For this group of participants, the swimming exercise increased muscle activation relative to the other 2 exercise modes. (J Manipulative Physiol Ther 2010;33:672-678)

Key Indexing Terms: Back Muscles; Electromyography; Rehabilitation; Exercise Therapy

Excessive fatigability of lumbar paraspinal muscles is often associated with chronic low back pain (LBP). Poor back extensor muscle endurance is, furthermore, a predictor of first-time occurrence of LBP and of long-term back-related disability when assessed 4 weeks postinjury. As concluded in a recent review, progressive resistance exercises for back muscles have been successful in increasing strength and/or endurance as well as decreasing pain and/or disability among patients with LBP.

There are several modes of exercise for improving the muscular function of the back. In the area of spine stabilization exercises, such as those that use floor mats or balls, the Pilates method has been gaining recognition recently as an optimal choice for improving spinal stability as well as the strength and/or endurance of trunk muscles (abdominal and lumbar). The weakness or fatigue of trunk muscles can increase the risk of neuromuscular deficits, which, according to Panjabi’s theory of the spinal stabilizing system, causes brief uncontrolled intervertebral movements. An unstable lumbar spine could contribute to tissue strain injury and subsequently to chronic back pain.

Pilates exercises, through the use of various approaches, emphasize the strengthening of both abdominal and lumbar muscles while promoting good posture and body alignment. The Pilates method integrates movement of the extremities in multiplane functional positions and correct spinal alignment with breathing and core centering.
EMG activity of back muscles during Pilates exercises. Several studies have investigated the electromyographic (EMG) activity of selected trunk muscles during specific spinal stabilization exercises. Arokoski et al. reported that some traditional lumbar stabilization exercise types such as quadruped, prone, and standing are effective for lumbar muscle activation. Souza et al. also observed significant back muscle activity (20%-30% of maximal activity) in different levels of quadruped exercise with ipsilateral leg raising. However, to the authors’ knowledge, no study has investigated the activity of lumbar muscles during the traditional Pilates mat exercises in the following: (1) swimming (SW), (2) single leg kick (SLK) in the prone position with static back extension, and (3) double leg kick (DLK). The purpose of this study was to examine the effect of 3 mat Pilates exercises (SW, SLK, and DLK) on the EMG activity of back muscles.

**Methods**

**Subjects**

Eleven healthy females, aged between 18 and 30 years, were recruited on a voluntary basis (university students and employees). The mean (standard deviation) characteristics of subjects were age = 22 (5) (year), height = 1.65 (0.6) (m), mass = 57.7 (8) (kg), and body mass index = 21 (1) (kg/m²). The exclusion criteria were as follows: back pain in the previous year, surgery on the musculoskeletal system of the trunk and legs, known congenital malformation of the spine or scoliosis, neurologic disease, current pregnancy, abnormal blood pressure, the use of medication to control cholesterol or triglyceride, or involvement in a new physical training program. All subjects had a good general physical aptitude and reported that they had never before performed Pilates exercises. The subjects were informed about the experimental protocol and the potential risks of the study and gave written consent before their participation. This study was previously approved by the Ethics Committee of the Universidade Estadual de Londrina, Londrina, Brazil (266/07).

**Procedures**

One session of approximately 2 hours was required for the experiment. The same investigator performed the all procedures and tasks with each subject to ensure uniformity. All exercises were demonstrated by a physical therapist trained in the Pilates method with experience as a Pilates instructor. The first step in the evaluation was to collect basic anthropometric measurements and to familiarize the subject with the equipment and the tasks. The second step was to assess back muscle activation during 3 traditional Pilates exercises (details below). The 3 sets of exercises were separated by 30 minutes of rest to minimize the effects of fatigue and were carried out randomly to control for possible confounding carryover effects.

**Maximal Voluntary Isometric Contraction**

For purposes of normalization, maximal voluntary isometric contraction (MVIC) was performed for back muscles to determine their maximal EMG activation. This choice was based on MVIC due to characteristics of the Pilates method, in which exercises are performed during expiration at a self-controlled velocity. Moreover, seeing that the range of motion in the spine is small during the exercises used in this study, it was reasonable to assume that there would be no significant change in muscle length and thus no significant effect in the EMG/force relationship. The subjects performed the MVIC while lying prone on a bench and positioned so that their anterior-superior iliac spines were aligned with the edge of the bench. The upper body was suspended horizontally and unsupported off the end of the bench, whereas the lower limbs (ie, thighs to feet) were restrained with tight-fitting self-stick straps; the arms were folded with hands crossed over opposite shoulders. The subjects started MVIC with the trunk slightly flexed in relation to horizontal and generated progressive back extension efforts against resistance on the upper back provided by an experienced physical therapist. Three MVICs, lasting 5 seconds each, were performed with verbal encouragement, allowing 5 minutes of rest between each. The largest value of the maximal EMG activation (details in processing signal) was retained as the MVIC.

**Pilates Exercises**

Ten minutes after the MVIC measurement and before executing the Pilates exercises, the subjects performed submaximal contractions to warm up, with stretching and mobilization of the spine, including spine stretch forward (stretching of the spine from the anterior trunk flexion in sitting position) and saw (stretching of the spine and combination of trunk forward flexion and rotation of the spine in sitting position). The subjects then performed one set of 8 repetitions lasting approximately 30 seconds for each of the following Mat Pilates exercise types (Fig 1): SW, SLK, and DLK. For SW, the subjects assumed a prone position, with arms extended overhead and lifted the trunk and legs during the execution of exercise (Fig 1A). For the duration of each exercise, the subjects maintained the neck in alignment with the spinal column (a principle of Pilates). The SLK exercise started with lumbar static hyperextension
(eg, maintenance of a static lordotic lumbar posture during the entire exercise) with hands placed on the mat (Fig 1B). The subjects alternated flexion and extension of the legs, such as kicking the heel toward the buttock for 2 pulses and then switching legs. Double leg kick (Fig 1C) was similar to SLK, except that subjects executed dynamic movements including simultaneous lifting of the legs and arms with concentric back extension (eg, extending the spine). The Pilates principles of body alignment, breathing control, and abdominal muscle control were emphasized throughout the exercise session. The EMG signals and video data were recorded simultaneously during the 3 sets.

Electromyography

An 8-channel electromyography system (MP150; BIOPAC Systems Inc, Aero Camino Goleta, CA), consisting of a signal conditioner with a band-pass filter with cutoff frequencies at 20 to 450 Hz, an amplifier gain of 2000 and a common mode rejection ratio of more than 120 dB was used to obtain the biological signals. All data were collected using specific software for acquisition and analysis (Acqknowledge 3.9.1; BIOPAC Systems Inc). Analog-to-digital conversion (16 bits) was set up with an antialiasing filter and a sampling frequency of 2000 Hz for each channel and an input range of 10 mV. Active bipolar electrodes were connected to a high impedance preamplifier (1.0 × 10¹² Ω).

After the skin at the electrode sites was shaved and abraded with 70% alcohol, the electrodes were positioned bilaterally over the multifidus (MU) at the L5 level (see Fig 2; MU-L5-Right [R] and MU-L5-Left [L]), following the recommendations of the Surface-EMG for the Non Invasive Assessment of Muscle, 3 cm from the midline of L5 spinous process. The interelectrode (center-to-center)
distance was 2 cm, taking muscle fiber direction into account.\textsuperscript{16} The reference electrode was placed on the nondominant wrist (in the styloid process of the ulna).

**Processing EMG Signal**

All EMG data processing was performed and analyzed using Matlab subroutines (7.7.0; The MathWorks Inc, Natick, MA). A notch filter was used for the EMG signals, removing frequencies at 60 Hz. From the EMG signals corresponding to the MVICs, a root mean square (RMS) processing method was executed on successive 250-millisecond (512 points) time windows (50\% overlapped). For each muscle, the peak RMS value across all MVIC trials represented the maximal EMG activity (RMS\textsubscript{MAX}). RMS\textsubscript{MAX} was used to compute the muscle activation level, which is the percentage of EMG amplitude relative to the maximal EMG obtained from largest interexercise MVIC.

The execution of each exercise lasted an average of 30 seconds. However, for EMG data analysis just the first 20 seconds of activity were considered. This was set to minimize the confounding effect of muscle fatigue on EMG activation analysis. A standard video camera 30 Hz (Sony) linked to the computer was used to manually synchronize the recording of both exercise performance and sEMG data. Thus, one person was filming while another began signal collection and then the subjects performed the exercise. Subsequently, the video was used to identify the signal corresponding to the phases of each movement. For SW, RMS values (250 milliseconds, 50\% overlapped) were computed using EMG signals from the concentric back extension phase while lifting the arms and legs. For each muscle, the mean RMS value was then computed to represent the mean RMS activity during the exercise (RMS\textsubscript{EXE, EXE = exercise}). For SLK, the RMS\textsubscript{EXE(r)} (\(r\) representing the number of repetitions) was computed for each repetition (lasting 2 seconds on average) from alternate movements of leg flexion with static back hypertension. For DLK, the RMS\textsubscript{EXE} was also computed for each repetition of the simultaneous lifting of the legs and arms with concentric back extension movement. In both exercises (SLK and DLK), the RMS\textsubscript{EXE(r)} values were then averaged over 5 repetitions to give a single value (RMS\textsubscript{EXE} mean of \(r\)). Finally, the activation level (\%) was computed for each muscle and Pilates exercise using the following equation:

**SW:**

\[
\text{Activation level (\%)} = \left(\frac{\text{RMS}_{\text{EXE}}}{\text{RMS}_{\text{MAX}}} \times 100\%\right)
\]

**SLK and DLK:**

\[
\text{Activation level (\%)} = \left(\frac{\text{RMS}_{\text{EXE(\text{mean of } r)}}}{\text{RMS}_{\text{MAX}}} \times 100\%\right)
\]

**Statistical Analysis**

All variables were normally distributed, as verified by the Shapiro-Wilk test. A 2-way repeated measures analysis of variance (2 muscles × 3 Pilates) on the Pilates factor (SW, SLK, and DLK) was performed to assess the differences in activation level during the exercises. Post hoc analyses were performed, when necessary, using the Tukey test. All statistical analyses were carried out with SPSS statistical software (version 15; SPSS Inc, Chicago, IL) with an \(\alpha\) of .05 set as statistical significance.

**RESULTS**

The activation level of the lumbar extensor muscles ranged between 15\% and 61\% of MVIC among the 3 Pilates exercises. No significant interaction (\(P \geq .05\)) was found between muscles and Pilates exercises for the activation level variable (Table 1). In both muscles, SW significantly increased muscle activation (29\% on average) compared to SLK and DLK (see Table 1). Also, DLK generated significantly more activity in the 2 lumbar extensor muscles than did SLK (Table 1). These results are further illustrated in Figure 3 with muscle data pooled because no significant differences between side muscles were found during the 3 exercise types (\(P = .09\)).

**DISCUSSION**

The Pilates method has been considered an optimal exercise modality for improving spinal stability as well as the strength and/or endurance of lumbar muscles.\textsuperscript{5} Several studies\textsuperscript{12,14,17,18} have investigated the activation of trunk extensor muscles during different modalities of back extension exercises to determine which would best improve back strength and endurance.

However, regarding Pilates exercises, few studies\textsuperscript{10,11} have assessed the recruitment pattern of trunk muscles during exercise. Endleman and Critchley\textsuperscript{10} evaluated trunk
muscle activity (abdominal only) during traditional and reformer Pilates approaches and only with the use of ultrasound measurements of muscle thickness, which do not correspond to the main outcome measure of the present study. Although Petrofsky et al. observed back extensor muscle activity using EMG, they evaluated Pilates modalities (90° and 45° squat, right and left abduction and hip extension) with respect to resistance devices and other muscle groups, not necessarily targeting back muscles. To the authors’ knowledge, this is the first study comparing the activity of lumbar muscles during traditional mat Pilates exercises. Three different mat Pilates exercises were assessed: SW, SLK, and DLK. The results of this study demonstrated that a progression of Pilates exercises can be assigned in order of back muscle activation load.

For example, back activity during SLK was low, on average 17% of maximal EMG activity/MVIC (Fig 3), and related to static lumbar hyperextension (ie, maintenance of a static lordotic lumbar posture). In fact, this exercise emphasizes only an alternating contraction during flexion and extension of legs without overloading the back muscles. Double leg kick activated the back muscles on average 42% of MVIC. This exercise involves intermittent concentric action of the trunk muscles with simultaneous back and bilateral leg extension while prone with the hands placed behind the back. A significant increase in back extensor activity is observed during prone back extension exercises when the relative trunk load is increased by modifying hand and lower limb position. The effect could be related to the relative weights of each segment (trunk + legs + arms) on the rotation axis of the lumbar spine during this exercise. Interestingly, the magnitude of this effect is comparable to the 53% difference found in prone back extension exercises, which require lifting the trunk and legs.

The main results of this study were that SW led to more lumbar extensor activity (29% on average) than the other exercises (Fig 3). As stated above, this may be related to load and moment arm length in this exercise. Generally, more lumbar torque is exerted when a load is positioned further from the axis of rotation along the moment arm. Swimming is performed with dynamic movements, moving the arms in the extended position and lifting the trunk and legs during the execution of exercise. Therefore, placing the hands and arms (part of the torso mass) further away from the axis of rotation results in a progressive increase in back muscle activity, as reported in other studies. Plamondon et al. found a peak level of 61% of maximum lumbar muscle activity in an exercise similar to SW that does not advocate Pilates principles, which agrees with the results of the present study.

Moreover, Sekendiz et al. showed that Pilates SW exercise was efficient at increasing the strength and endurance of trunk muscles in healthy adult females. Based on our results, the 59% back activation achieved during this exercise would be sufficient to elicit physiologic changes and subsequently localize the effects of endurance training on the back muscles.

Although several studies have investigated back muscle activation during a range of back extension exercises such as specific spinal stabilization exercises, prone back extension, roman chair, and machine-based exercises, none used Pilates principles (body alignment, breathing control, and abdominal control). The

### Table 1. Activation values (% MVIC) of the lumbar extensor muscles during mat Pilates exercises

<table>
<thead>
<tr>
<th>Variable</th>
<th>Muscles</th>
<th>Pilates exercises</th>
<th>P Analysis of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activation (MVIC %)</td>
<td>MU-L5-R</td>
<td>SW 61 (21) SLK 19 (11) DLK 47 (21)</td>
<td>0.0091 Tukey test results SW &gt; SLK, DLK DLK &gt; SLK</td>
</tr>
<tr>
<td></td>
<td>MU-L5-L</td>
<td>57 (14) 15 (10) 39 (17)</td>
<td></td>
</tr>
</tbody>
</table>

Analysis of variance results: main effects on muscles in the Pilates exercises. Values are presented as mean (SD). The significant differences were identified with **bold** characters. Muscles: MU-L5-R indicates multifidus at the L5 right side level; MU-L5-L, multifidus at the L5 left side level; >, identifies more back activation between conditions from Tukey post hoc test. Pilates exercises: swimming (SW), single leg kick (SLK) in the prone position with static back extension, and double leg kick (DLK).
results of this study will help in the design of an exercise program specifically for back muscles using a Pilates approach. As suggested in a recent review, specific back exercises are more efficient for the treatment of LBP. Mat Pilates work is simpler and more cost-efficient for strengthening lumbar extensors than exercise using machines or dynamometers. However, it is still unclear if the Pilates’ method provides similar overload stimulus compared to machines for eliciting strength and endurance gains in back muscles. Further studies are required to compare the muscle activation in these exercises with different populations and age groups, as well as with other exercises types (eg, Pilates vs Roman chair and/or Pilates vs machines). This measure could provide a better understanding of the effect of exercise on muscle and become a prerequisite for the prescribing of spine stabilization, endurance, or muscular strength training.

**Limitations**

This study has some limitations that need to be addressed. These results only apply to traditional mat Pilates exercises. They cannot automatically be generalized to patients with LBP, who may have different back activation patterns, nor to male subjects, because some studies have found a sex effect on back activation. The activation of abdominal muscles and hip extensors was not assessed. Furthermore, these results apply only to superficial lumbar muscles seeing that no deep back muscles were investigated using intramuscular EMG.

**Conclusion**

The electrical muscle activity of lumbar extensors ranged from 15% to 61% during 3 mat Pilates exercises. In both muscles, the SW exercise significantly increased muscle activation (29% on average) relative to the other 2 exercise modes. This exercise may be a useful way to focus the effects of endurance training on the back muscles.

**Practical Applications**

- The swimming exercise significantly increased muscle activation compared to single leg kick and double leg kick.
- The single leg kick is an exercise that emphasizes only an alternating contraction during flexion and extension of legs without overloading the back muscles.

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**Funding Sources and Potential Conflicts of Interest**

No funding sources or conflicts of interest were reported for this study.

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