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MUSCLE PHYSIOLOGY

Electromyographic activity of rectus abdominis muscles during dynamic Pilates abdominal exercises

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Summary *Objective:* To assess the electrical behaviour of the upper rectus abdominis (URA) and lower rectus abdominis (LRA) by electromyography (EMG) during the following dynamic Pilates abdominal exercises: *roll up*, *double leg stretch*, *coordination*, *crisscross and foot work*. The results were compared with EMG findings of traditional abdominal exercises (*sit up* and *crunch*). Methods: Seventeen female subjects (with no experience of the Pilates method) were recruited. The URA and LRA were evaluated while 12 isotonic contractions were performed using the Pilates principles or traditional abdominal exercises. The data were normalised by a maximal voluntary isometric contraction. Normality was accepted, and ANOVA followed by Tukey test was used to determine data differences ($P < 0.05$). Results: Pilates exercises *double leg stretch*, *coordination*, *crisscross* and *foot work* promoted greater muscle activation than traditional exercises, mainly in URA. Thus, these exercises have the potential to be prescribed for muscle strengthening programmes.

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Introduction

The Pilates method is a body exercise technique that has been widely used in recent years by therapists in order to improve flexibility, physical fitness and body awareness and to strengthen the muscles mainly associated with trunk stability (Shedden and Kravitz, 2006; Latey, 2001). The entire construction of the theoretical concepts related to this method was developed by Joseph Pilates (1886—1967) during the First World War with the aim of rehabilitating the injured (Shedden and Kravitz, 2006; Latey, 2001). The method became popular during the 1980s, but the scientific validity that could sustain the prescribed exercises is still lacking (Muscolino and Cipriani, 2004).

Research is necessary to give scientific support to the philosophical and conceptual premises of Pilates if it is to be systematically included in rehabilitation and training programmes. In recent years, several studies related to Pilates exercises have been published (Aladro-Gonzalvo et al., 2013, 2012; Barton and McNeill, 2012; Sekendiz et al., 2007), but the literature still lacks electromyography (EMG) findings to characterise the activity of the muscles involved during the execution of the numerous movements of this method. For instance, the dynamic stability of the spinal column is routinely trained by practitioners of the Pilates method with the application of exercises that purport to strengthen specific muscle groups, such as spine extensors, hip extensors, hip flexors, deep muscles of the pelvis and rectus abdominis (Kolwniak et al., 2004). Weakness of these muscles is associated with low back pain, and the effectiveness of Pilates in low back pain has been documented (Conceição, 2012; Holmstrome et al., 1992).

It has been shown that small changes in a Pilates exercise method can change the pattern of muscle electrical activation (Loss et al., 2010; Silva et al., 2013a). Menacho et al. (2010) subjected the paraspinal muscle to three Pilates exercises: *swimming*, *single leg kick* and *double leg kick*. Using EMG, distinct contribution of the paraspinal muscle was observed in each of the exercises. Values for electrical muscle activity ranged between 15% and 61% of maximum isometric voluntary contraction (MIVC) for the 3 types of Pilates mat work exercise. However, there is insufficient information in the literature to secure inclusion of the method, especially in patients with musculoskeletal disorders. Thus, it is critical to characterise the exercises of this method more thoroughly, especially in relation to the muscles acting on the spine (Loss et al., 2010; Silva et al., 2013).

It has been noted that the rectus abdominis muscle is the major flexor of the torso compared with other muscles in the abdominal wall and that it plays a significant role in spine stability (Norwood et al., 2007). However, controversy exists around exercises that attempt to differentially activate the upper (URA) or lower (LRA) portion of the rectus abdominis muscle (Sarti et al., 1996; Lehman and McGill, 2001; Clark et al., 2003; Duncan, 2009). In this sense, understanding which abdominal muscles are recruited and how active they are while performing a variety of Pilates and traditional abdominal exercises is helpful to therapists and other health professionals in developing specific abdominal exercises for their patients or clients, to facilitate their rehabilitation or training objectives.

Thus, owing to the current lack of clarity in the use of EMG to evaluate rectus abdominis activity during the Pilates method, this study aimed to assess the EMG features of URA and LRA of dynamic Pilates abdominal exercises (*roll up*, *double leg stretch*, *coordination*, *crisscross and foot work*) and two traditional abdominal exercises (*sit up* and *crunch*).

Material and methods

Participants

A total of 17 right-handed women with a mean height of 1.67 $\pm$ 0.71 m, body weight 64.2 $\pm$ 6.9 kg and mean age of 20.3 $\pm$ 5.2 years, were recruited on a voluntary basis (university students). The inclusion criteria were: (a) women were physically active and with no history of musculoskeletal injury, (b) no previous pregnancy, (c) no visually identified asymmetries of the trunk and lower limbs, (d) no prior experience with Pilates, and (e) familiar with the *sit up* and *crunch* exercises (traditional abdominal exercises). The study followed the ethical guidelines for human experimentation, according to Brazilian Law 196/96 of the National Health Council.

Data recording

The four-lead EMG system Miotool 400 (Miotec, Equipamentos Biomédicos, Porto Alegre, RS, Brazil) linked to a personal computer was used to record muscle activity. The system specifications include a common mode rejection ration (CMRR) of 110 dB and a gain of 200$\times$. The EMG signals were collected using a sampling rate of 2000 Hz and stored in a computer with a 14 bit A/D card (Miotec, Equipamentos Biomédicos, Porto Alegre, RS, Brazil). Muscle activation of the right upper rectus abdominis (URA) and lower rectus abdominis (LRA) were collected for each participant using bipolar surface disc electrodes (Ag—AgCl, Meditrace, Mansfield, MA, USA) measuring 10 mm in diameter with an inter-electrode distance of 20 mm. Before electrode placement, the skin was trichotomised, swabbed with alcohol 70% and abraded with sandpaper to reduce impedance. The electrodes were placed on the muscle bellies and positioned parallel to the muscle fibres using the techniques described by Basmajian and Deluca (1985) and according to the EMG for the Non-Invasive Assessment of Muscles (SENIAM) recommendations (Hermens et al., 1999): the 'URA electrode' was placed approximately just below the midpoint between the umbilicus and xiphoid process, but not at the tendon intersection, and 3 cm lateral from the midline. The 'LRA electrode' was placed approximately at the midpoint between the umbilicus and the pubic symphysis and 3 cm lateral from the midline (Fig. 1). A reference electrode was placed on the middle third of the clavicle.

The EMG analysis was performed using custom-made Miograph 2.0® software (Miotec, Equipamentos Biomédicos, Porto Alegre, RS, Brazil). All EMG signals were band-pass