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EXERCISE PHYSIOLOGY

EMG activity of trunk stabilizer muscles during Centering Principle of Pilates Method

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Summary This study aimed to analyze the electromyographic (EMG) activity of iliocostalis lumborum (IL), internal oblique (IO) and multifidus (MU) and the antagonist cocontraction (IO/MU and IO/IL) during the performance of Centering Principle of Pilates Method. Participating in this study were eighteen young and physically fit volunteers, without experience in Pilates Method, divided in two groups: low back pain group (LBPG, $n = 8$) and control group (CG, $n = 10$). Two isometric contractions of IO muscles (Centering Principle) were performed in upright sitting posture. EMG signal amplitude was calculated by Root Mean Square (RMS), which was normalized by RMS maximum value. The common area method to calculate the antagonist cocontraction index was used. MU and IO activation and IO/MU cocontraction ($p < 0.05$) were higher in CG. The CG therefore showed a higher stabilizer muscles recruitment than LBPG during the performance of Centering Principle of Pilates Method.

Introduction

Non-specific low-back pain is musculo-skeletal symptom of high incidence, which affects, approximately, 80% of the adult western population (da Fonseca et al., 2009). It is estimated that 5—15% of non-specific low-back pain cases become chronic, resulting in high costs for health and social security systems (Gaskell et al., 2007). Alterations in muscular recruitment, decrease of force generation capacity and the endurance potential of deep abdominal

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muscles are among probable causes of low-back pain (da Fonseca et al., 2009; O'Sullivan et al., 1997; van Dieën et al., 2003a,b).

Accordingly, the search for low-back pain treatments, especially low-cost ones, is necessary. Physical exercise is among the interventions, which has the goal to improve muscular function (Kakaanpaa et al., 1999). Currently, exercises known as "segmental stabilizer exercises" are considered an important resource of physical therapy to prevent and rehabilitate non-specific low-back pain (Franca et al., 2008). Within this exercise modality, Pilates Method therapy is widely used in the clinical practice of physiotherapists (Bryan and Hawson, 2003).

Pilates Method therapy is indicated to prevent and rehabilitate non-specific low-back pain, since it promotes high stability for vertebral segments, as a result of a specific training for deep trunk muscles (Muscolino and Cipriani, 2004). Thus, the aim of this exercise modality is the automation of a specific muscular recruitment pattern, also improving the endurance of trunk muscles (Bryan and Hawson, 2003).

Pilates Method exercises are based on eight principles: Concentration, Control, Centering, Flow, Precision, Breath, Relaxation and Routine. Among these, the Centering Principle, which consists of an isometric contraction of the internal oblique muscles, stands out. Moreover, the Centering Principle must be maintained during all exercises in order to enhance the lumbar spine stability (Bryan and Hawson, 2003; Gladwel et al., 2006).

Stability is defined as the capacity of a system to maintain equilibrium even after the occurrence of external disturbance (Granata and Orishimo, 2001). Thus, there are motor control strategies that seek to preserve and improve joint stability, such as the higher activation of joint stabilizer muscles and increased antagonist co-contraction (van Dieën et al., 2003a,b). In the case of Centering Principle, both strategies are involved.

Although widely used in physical therapy, there is little information about the effect of Pilates Method exercises on the musculo-skeletal system (Silva et al., 2009). Thus, considering the high incidence of low-back pain and the importance of the development of prevention strategies and treatment for this disability, the present study aimed to analyze the electromyographic activity (EMG) of iliocostalis lumborum (IL), internal oblique (IO) and multifidus (MU) muscles and the antagonist cocontraction (IO/MU and IO/IL) during the performance of the Centering Principle in the Pilates Method. It has been hypothesized that individuals with low-back pain have reduced lumbo-pelvic stability because they have low stabilizer trunk muscles activation and antagonist cocontraction.

Methods

Participants

Twenty-one physically fit female subjects without any experience on Pilates Method exercises were recruited from a university setting; however, three volunteers were excluded due to technical problems. Thus, data from eighteen volunteers were considered in this study.The participants were divided into two groups: low-back pain group (LBPG) and control group (CG), according to self-reported low-back pain within a period of six months prior to the study (Tsao and Hodges, 2008). LBPG group was composed of 8 volunteers and CG group was composed of 10 volunteers. Individuals from both groups had similar age, mass, height and physical activity level (Table 1).

Subjects with prior history of spinal and abdominal surgery as well as major orthopedic, neurological or cardiorespiratory disorders were excluded. All volunteers were previously informed about data collection procedures and signed the consent form, and the study was approved by a local Ethics Committee.

Protocol

The data collection protocol was performed over two days, with an interval of 24—72 h between each day. On the first day, volunteers were familiarized with the data collection environment and answered a subject characterization form with personal information such as age and physical activity level. On the second day, volunteers were familiarized with the IO isometric contraction by visual feedback provided by EMG signal at a monitor in front of the volunteer (Fig. 1). Then, two IO isometric contractions were performed (Centering Principle) until voluntary exhaustion, with a rest of 3 min between each contraction (Table 2).

The IO isometric contraction (Centering Principle) was performed in an upright sitting position with hip and knees in flexion at approximately 90° (O'Sullivan et al., 2002, 2006). All volunteers were required to maintain this posture during the contraction. In addition, in order to maintain the upright sitting position, the volunteers received visual feedback from a monitor positioned in front of them, which projected their sagittal plane images. A camera (Panasonic®) was used to capture the images and photoreflexive markers were positioned on the acromion, spinous process of L1 and greater trochanter (Fig. 2).

Electromyography

EMG signal data collection was performed with electromyography of four channels and two accessories (EMG System®), surface Ag/AgCl electrode discs (Meditrace®), with an active area of 1 cm^2 and an inter-electrode distance of 2 cm were used in a bipolar configuration.

The electrodes were positioned at the right side on the muscles: internal oblique (IO), at 2 cm medially and

Table 1 Values of mean and standard deviation of age, mass, stature and level of physical activity per week of individual of low back pain group and control group.

	Low back pain group (n = 8)	Control group (n = 10)
Age (years)	19.5 (1.1)	20.8 (2.4)
Mass (Kg)	59.6 (7.1)	61.2 (8.4)
Stature (m)	1.6 (0.05)	1.6 (0.06)
Level of physical activity (days/week)	3.6 (1.5)	3.7 (1.3)

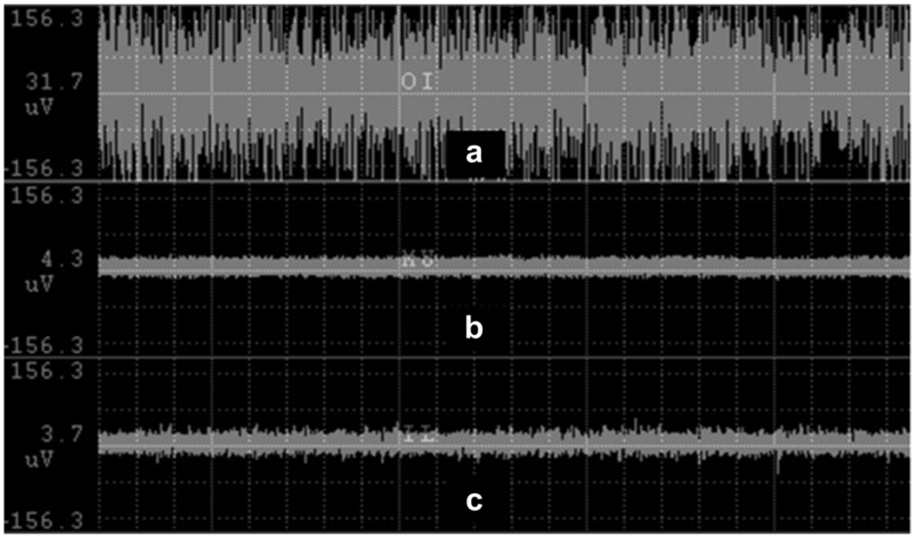

Figure 1 Electromyographic activity of internal oblique, (a) multifidus, (b) and iliocostalis lumborum, (c) during Centering Principle of Pilates Method.

inferiorly to the anterior superior iliac spine; iliocostalis lumborum (IL), 6 cm laterally to the space between the spinous processes of L2-L3; and multifidus (MU), at 2 cm laterally to the space between the spinous processes of L4-L5 (Marshall and Murphy, 2003; Barbosa and Gonçalves, 2005). Furthermore, a reference electrode was placed on the right antero-superior iliac spine and, before placing electrodes, the skin was shaved and cleaned with alcohol (Hermens et al., 2000).

EMG signal was recorded at a sample rate of 1000 samples/s and after amplification with total gain of 2000 times (20 times in the pre-amplifier at the electrodes and 100 times in the amplifier). Then, the EMG signal was processed with band-pass filtered between 20 Hz and 500 Hz, and a notch filter of 60 Hz was also used.

Data analysis

EMG analysis was performed using custom-made Matlab (Mathworks 7.0) environment. EMG signal was processed in time domain, thus obtaining the Root Mean Square (RMS) and IO, MU and IL values. RMS values were normalized by maximum RMS obtained during contractions of each muscle.

Table 2 Values of mean of the first and second trial of Centering Principle in seconds of individual of low back pain group and control group.

	Low back pain group (n = 8)	Control group (n = 10)
First trial of Centering Principle (seconds)	319.6	151.4
Second trial of Centering Principle (seconds)	250.6	280.1

The co-contraction percent between IO/MU and IO/IL were calculated during all IO isometric contraction, using equation (1) (Candotti et al., 2009),

$$\%COCON = 2 \times \frac{\text{common area AB}}{\text{area A} + \text{area B}} \times 100 \quad (1)$$

where %COCON is the co-contraction percent between two antagonist muscles (IO and MU; IO and IL), area A below the EMG is the smoothed curve of muscle A, area B below the EMG is the smoothed curve of muscle B, common area A&B

Figure 2 Upright sitting position and photoreflexive markers during the Centering Principle task and Pilates Method.

is the common area of activity between these antagonist muscles.

Using the PASW 18.0 package (SPSS Inc.), the comparisons between LBPG and CG for the RMS values and %COCON, the t-Student test for independent samples was used, and significance level was set at $p < 0.05$.

Results

During the first Centering Principle trial, CG had higher IO activation than LBPG ($p = 0.009$) and in the second Centering Principle trial, the CG had higher MU activation than LBPG ($p = 0.001$) (Fig. 3).

For the co-contraction percent between IO/IL, in both trials, no differences between groups were found. However, the co-contraction percent between IO/MU, in both trials, was higher in the CG ($p = 0.004$; and $p = 0.043$) (Fig. 4).

Discussion

Pilates Method was developed at the beginning of twentieth century by Joseph Pilates (Siler, 2000). However, this exercise method became more practiced in the decade of 1980, first by dancers and then by physiotherapists (Anderson and Spector, 2000; Emery et al., 2010). Currently, these exercises are widely used for prevention and rehabilitation of musculo-skeletal dysfunction, such as non-specific low-back pain (Franca et al., 2008).

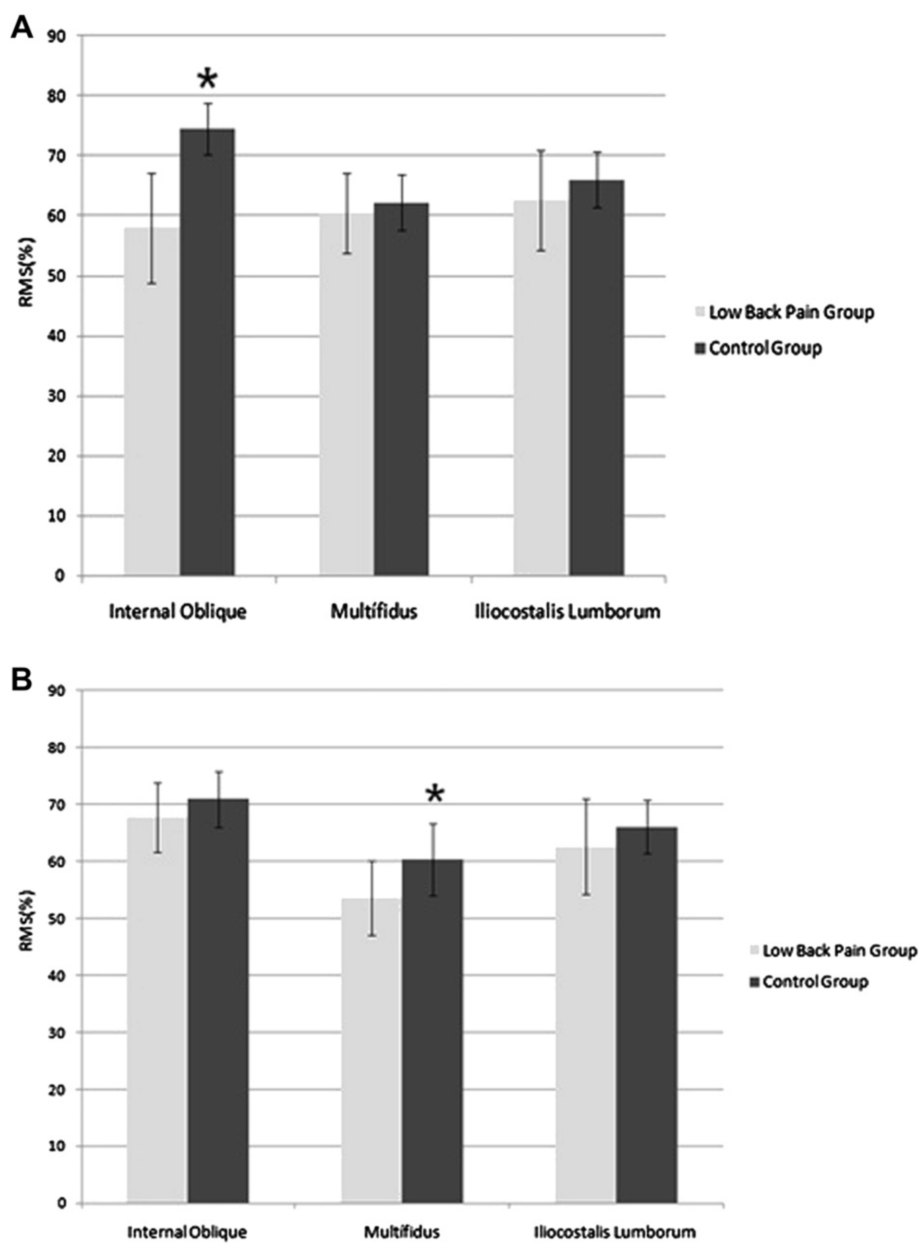

Figure 3 (A) Values of RMS of IO, MU and IL muscles during the first trial of Centering Principle, (B) and during the second trial of Centering Principle (*$p < 0.05$).

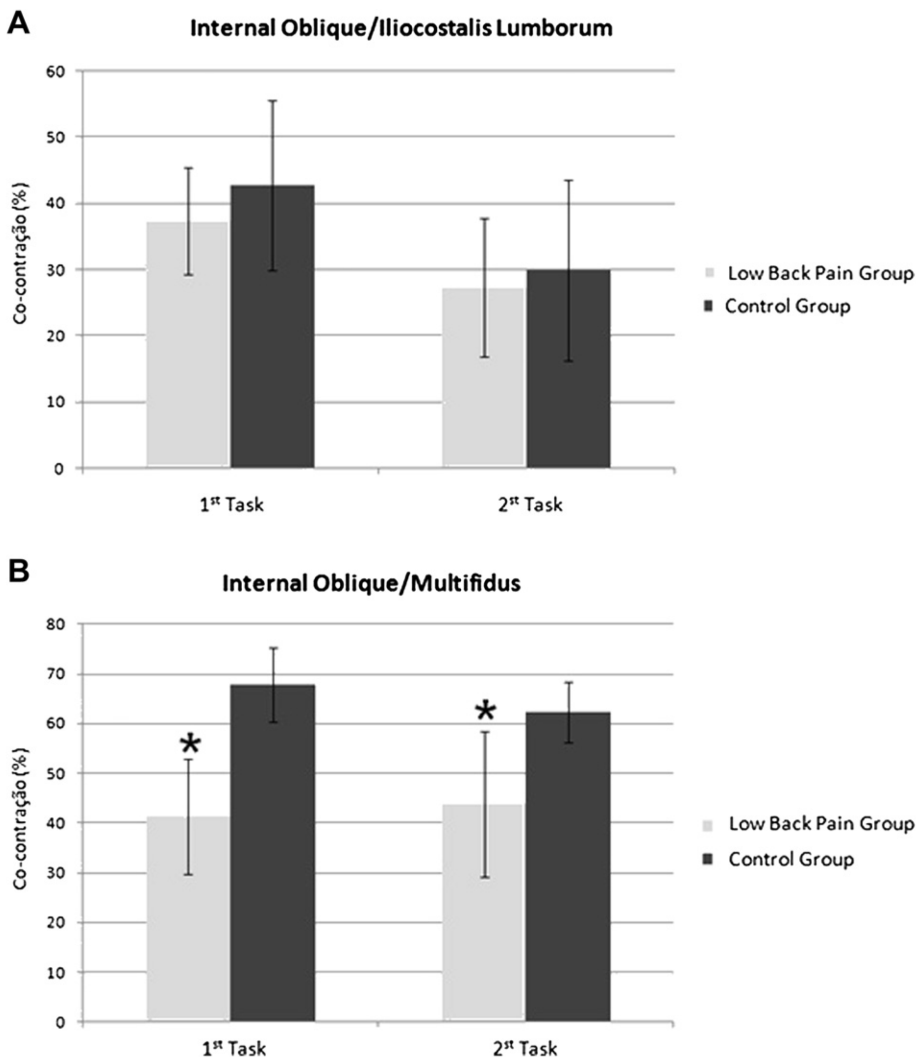

Figure 4 (A) Percent of cocontraction between IO/IL during the first and second trials of Centering Principle, (B) Percent of cocontraction between IO/MU during the first and second trials of Centering Principle (*$p < 0.05$).

Thus, the sample used in our study was composed of volunteers without experience of Pilates Method practice to analyze the EMG activity of trunk muscles in patients with low-back pain and healthy individuals during the performance of Centering Principle. Moreover, the results found agree with our hypothesis that healthy individuals have more activity of trunk stabilizer muscles and antagonist co-contraction during the isometric contraction of IO muscle.

EMG is a biomechanical technique widely used for the evaluation of muscular function and the calculation of RMS allows verification of the amplitude of muscular activation. Thus, high RMS values indicate a high number of active motor units (De Luca, 1997). In this sense, healthy individuals have higher recruitment of motor units during the isometric contraction of IO muscle, which is evidence of better motor control of this region. Previous studies showed that decreased and delayed trunk muscles activation are common findings in non-specific low-back pain (Hodges and Richardson, 1996; Moseley et al., 2004; O'Sullivan et al., 1998; Richardson and Jull, 1995; Hodges and Richardson, 1996). In addition, another research study (Astfalck et al., 2010) identified that IO muscle had, during sitting position, higher activation in healthy individuals than patients with low-back pain.

During Centering Principle, CG presented higher MU activation, which could be related with an improvement of the antagonist cocontraction as a motor control strategy to provide more spinal stability (Cholewicki et al., 1997; Gardner-Morse and Stokes, 2001; Granata and Marras, 2000; van Dieën et al., 2003a,b).

Antagonist co-contraction may have two functions: to stabilize the spine due the increased joint stiffness, and for joint motor control, since the joint stiffness during movement is modulated to manage disturbances in the neuromotor system (Cholewicki et al., 1997; Gardner-Morse and Stokes, 2001; Granata and Marras, 2000; van Dieën et al., 2003a,b). According to data obtained, healthy individual have higher antagonist co-contraction, which provide more stability and is responsible for a better load distribution at the lumbar spine (Dolan et al., 1994). However, antagonist co-contraction between IO/IL showed no significant difference between groups. This finding may be related to IL function, which is not directly involved with spinal stability (O'Sullivan et al., 2002, 2006).

In our study, the load imposed in isometric contraction was not controlled, as during the Pilates Method practice. Moreover, the occurrence of cross-talk of the EMG signal between IO and tranversus abdominis muscle is possible, but in the Centering Principle, the transversus abdominis contraction must occur, so the EMG signal of IO is accepted as an important indication of spinal stability, although the exact contribution of each muscle is unknown (Anders et al., 2007).

Conclusion

According to our results, it could be concluded that patients with low-back pain had decreased activation and antagonist co-contraction of trunk stabilizer muscles, which could be related with an impaired motor control of this region. In addition, impaired lumbar spine stability in patients with low-back pain during Centering Principle of Pilates Method is an important finding for physiotherapists to prescribe these exercises.

Ethical approval

Number of Ethics Committee Approval: 67/2009.

Conflict of interest

No potential conflict of interest between the authors.

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