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Immediate effect of a Pilates method exercise session on the co-contraction pattern of the trunk stabilizing muscles in individuals with and without nonspecific chronic low back pain

Efeito imediato de uma sessão de treinamento do método Pilates sobre o padrão de cocontração dos músculos estabilizadores do tronco em indivíduos com e sem dor lombar crônica inespecífica

Efecto inmediato de una sesión de entrenamiento del método Pilates sobre el estándar de cocontracción de los músculos estabilizadores del tronco en individuos con y sin dolor lumbar crónico inespecífico

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ABSTRACT | This study aimed to analyze the immediate effect of a Pilates method exercise session on the co-contraction pattern (agonist/antagonist) of the superficial (iliocostalis lumborum and rectus abdominis) and deep (internal oblique and multifidus) muscles of the trunk in individuals with and without low back pain during local muscle endurance test. Participated in the study adult subjects of both gender, aged between 19 and 59 years, separated into two groups: the group with low back pain (n=9) and the group without low back pain (n=9). Electromyographic signals of the following muscles were collected: internal oblique (IO), multifidus lumborum (MU), iliocostalis lumborum (IL) and rectus abdominis (RA), during maximal voluntary isometric contractions and Biering-Sorensen test, before and after the exercise protocol performance of the Pilates method. The co-contractions between IO/MU right and left (IO/MUr, IO/MUl) and RA/IL right and left (RA/ILr and RA/ILl) were calculated. The co-contraction between IO/MUr, IO/MUl, RA/ILr and RA/ILl was respectively 41.4, 32.4, 56 and 31.2% higher in the group with low back pain (p<0.001 and p=0.003, p=0.004 and p=0.01). The initial condition presented antagonist co-contraction 26.3 and 43.4% higher between IO/MUr (p=0.023, p=0.03). A training session with Pilates method exercises was able to reduce co-contraction between the trunk muscles (in individuals with and without nonspecific low back pain).

Keywords | Exercise and Movement Techniques; Electromyography; Low Back Pain.

RESUMO | Este estudo teve por objetivo analisar o efeito imediato de uma sessão de exercícios do método Pilates sobre o padrão de cocontração (agonista/antagonista) dos músculos superficiais (iliocostal lombar e reto abdominal) e profundos (oblíquo interno e multífido) do tronco em indivíduos com e sem dor lombar durante teste de resistência muscular localizada. Participaram do estudo sujeitos adultos, de ambos os sexos, com idade entre 19 e 59 anos, separados em dois grupos: grupo com dor lombar (n=9) e grupo sem dor lombar (n=9). Foram coletados os sinais eletromiográficos dos músculos: oblíquo interno (OI), multífido lombar (MU), iliocostal lombar (IL)

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e reto abdominal (RA), durante as contrações isométricas voluntárias máximas e o teste de *Biering-Sorensen* antes e após a realização do protocolo de exercícios do método Pilates. Foi calculada a cocontração entre OI/MU direito e esquerdo (OI/MUd, OI/MUe) e RA/IL direito e esquerdo (RA/ILd e RA/ILe). A cocontração entre OI/MUd, OI/MUe, RA/ILd e RA/ILe foi, respectivamente, 41,4, 32,4, 56 e 31,2% maior no grupo com dor lombar (p<0,001 e p=0,003, p=0,004 e p=0,01). A condição inicial apresentou cocontração antagonista 26,3 e 43,4% maior entre OI/MUd (p=0,023, p=0,03). Uma sessão de treinamento com exercícios do método Pilates foi capaz de reduzir a cocontração entre os músculos do tronco (em indivíduos com e sem dor lombar inespecífica).

Descritores | Técnicas de Exercício e de Movimento; Eletromiografia; Dor Lombar.

RESUMEN | Este estudio tuvo por objetivo analizar el efecto inmediato de una sesión de ejercicios del método Pilates sobre el estándar de cocontracción (agonista/antagonista) de los músculos superficiales (iliocostal lumbar y recto abdominal) y profundos (oblicuo interno y multífido) del tronco en individuos con y sin dolor lumbar durante la prueba de resistencia muscular localizada. Participaron del estudio sujetos adultos, de ambos sexos, con edad entre 19 y 59 años, divididos en dos grupos: el grupo con dolor lumbar (n=9) y el grupo sin dolor lumbar (n=9). Fueron recogidas las señales electromiográficas de los músculos: oblicuo interno (OI), multífido lumbar (MU), iliocostal lumbar (IL) y recto abdominal (RA), durante las contracciones isométricas voluntarias máximas y la prueba de *Biering-Sorensen* antes y después de la realización del protocolo de ejercicios del método Pilates. Fue calculada la cocontracción entre OI/MU derecho e izquierdo (OI/MUd, OI/MUi) y RA/IL derecho e izquierdo (RA/ILd y RA/ILi). La cocontracción entre OI/MUd, OI/MUi, RA/ILd y RA/ILi fue, respectivamente, el 41,4, el 32,4, el 56 y el 31,2% más grande en el grupo con dolor lumbar (p<0,001 y p=0,003, p=0,004 y p=0,01). La condición inicial presentó cocontracción antagonista el 26,3 y el 43,4% más grande entre OI/MUd (p=0,023, p=0,03). Una sesión de entrenamiento con ejercicios del método Pilates fue capaz de reducir la cocontracción entre los músculos del tronco (en individuos con y sin dolor lumbar inespecífico).

Palabras clave | Técnicas de Ejercicio y de Movimiento; Electromiografía; Dolor Lumbar.

INTRODUCTION

Low back pain is a musculoskeletal dysfunction of high incidence[1] and of multifactorial nature[2,3]. This dysfunction affects approximately 80% of the Western population at least once throughout life, and 5-15% of the cases become chronic[4]. Nonspecific chronic low back pain is defined as persistent pain and dysfunction for more than three months without a clear and specific cause[5] and corresponds to more than 85% of low back pain cases[6].

In the musculoskeletal system, specifically in the lumbar spine, the joint and integrated action of three subsystems is the required factor in maintaining the stability of this region. These three subsystems, responsible for the lumbar spine stability are called: active, which is composed of the muscles and tendons of the ventral and dorsal region of the trunk; passive, formed by the articular structures of the spine; and neural, constituted by afferent, efferent nervous structures and neural control centers[7].

Among the three subsystems presented by Panjab[7], studies indicate that subjects with chronic nonspecific low back pain present alterations mainly in the active and neural subsystems, since they provide stability in both static and dynamic conditions[3,8]. In the static condition, stability maintenance occurs through the co-contraction of the abdominal and paravertebral muscles (multifidus and oblique internal/transverse abdominal), which increases intervertebral stiffness. However, increased co-contraction between the superficial muscles (iliocostalis/rectus abdominis) may represent a compensatory strategy for low back pain and leads to segmental instability, a pattern observed in individuals with chronic low back pain[9].

Currently, lumbar-pelvic segmental stabilization exercises are indicated in physiotherapy for the prevention and rehabilitation of low back pain with unknown origin[10]. Lumbar-pelvic segmental stabilization exercises are characterized by isometry, low intensity and synchronized activation of the deep trunk muscles. Among the lumbar-pelvic segmental stabilization exercises are those of the Pilates method, aiming at automating muscle recruitment patterns, as well as improving the trunk muscles conditioning, which is directly related to the maintenance of the lumbar region stability[11].

Pilates method has eight principles, essential for the practice of exercises: concentration, centering, breathing, control, precision, flow, integrated isolation and routine. Centering stands out among those principals and it refers to the maintenance of isometric contraction of the spine stabilizing muscles (transverse abdominal, internal oblique and multifidus)[12]. The greater activation of the articular stabilizing muscles and the increase of the antagonist co-contraction are some of the existing strategies of motor control that seek to preserve or maintain the stability of a joint[9].

Tsao and Hodges[13] demonstrated that there is an immediate effect of motor training in modifying anticipatory postural adjustments. In this study, there was a time reduction to onset the transverse abdominal muscle after the exercises, which suggests that the voluntary contraction repetition of the trunk stabilizing muscles generated motor learning[13]. However, the transfer from this motor learning to functional activities, such as isometric force maintenance by trunk extensors, is not yet known.

Thus, the objective of this study was to analyze the immediate effect of a Pilates method exercise session on the co-contraction pattern (agonist/antagonist) of the superficial (iliocostalis lumborum and rectus abdominis) and deep (internal oblique and multifidus) muscles of the trunk in individuals with and without nonspecific chronic low back pain. Considering the findings of Tsao and Hodges[13] and due to the characteristics of the training with Pilates method exercises are similar to those used by these authors. The initial hypothesis of this paper is that the exercises with Pilates method can promote changes in the pattern of trunk stabilizers muscles recruitment. Thus, it is expected that, immediately after training with Pilates method exercises, the increase co-contraction of the deep trunk stabilizing muscles (internal oblique/multifidus) occur during the Biering-Sorensen test, which requires the isometric force maintenance of the muscles trunk extensors.

METHODOLOGY

Sample

Eighteen adult subjects (19-59 years old) of both genders were part of the study and were separated into two groups: control group (CG), composed of individuals without low back pain (n=9); and a group with low back pain (GLBP, n=9), composed of individuals with nonspecific chronic low back pain. Individuals from both groups were recruited into the university community from a waiting list for physiotherapeutic treatment of a school-based clinic. The anthropometric characteristics of the participants are described in Table 1.

Table 1. Characterization of the sample

Variable	Group with low back pain	Group without low back pain	p
Age (years)	28.9±4.01	28.7± 2.1	0.9
Body mass (kg)	68.7±13.9	61.1±13.1	0.2
Height (m)	1.7±0.08	1.6±0.1	0.6
Visual analogue scale (score)	1.3±2.2	–	–

The sample size (n=18 volunteers) was determined from the mean and standard deviation data obtained in a pilot study (n=5 volunteers per group) using the G*Power 3.0 program, considering as outcome variable the co-contraction between rectus abdominis/iliocostalis lumborum in the group with low back pain (effect size = 0.75, power = 0.9, and α=5%). This study was approved by the local Research Ethics Committee and all participants signed the Informed Consent Form.

The eligibility criteria to participate in the GLBP were: reports of multiple low back pain episodes in the three months prior to the study evaluation, characterize the presence of chronic low back pain, and physical conditions that allow the tests to be performed. If the low back pain appears at the time of evaluation, it is measured by the visual analogue scale. In the Control Group, subjects who did not present low back pain in the last 12 months prior to the study were included.

To be part of the study, none of the subjects could present: restriction to perform the complete shoulder flexion movement on the dominant side; obesity (IMC≥30kg.m2); vertebral deformities leading to function loss; history of lumbar surgery; history of neuromuscular or joint disease; cognitive deficit; current gestation or delivery within six months prior to study participation; presence of another chronic painful pathology; prior experience with Pilates method exercises; and inability to reproduce the proposed exercises.

Procedures

The data collection procedure was performed in two visits to the collection environment, separated by a 24-hour interval. At the first visit, the personal data to identify the subjects were collected and stored in a digital file. To ensure the survey confidentiality, each volunteer's name was replaced by an identification number listed in the documents of this study. Participants were then evaluated through a form for anthropometric data collection, skinfold measurement, anamnesis, information related to the participant's occupation, and the visual analog pain scale. Individuals selected for GLBP responded to the Roland Morris Disability Questionnaire to assess the functional impairment of participants with chronic nonspecific low back pain in daily activities. The questionnaire consists of 24 statements and participants should only indicate those that correspond to their current condition. Subsequently, the volunteers were familiarized with the Pilates method exercise protocols. All participants were instructed not to train the exercises outside the collection environment so that the results were derived only from the intervention protocol.

At the second visit, the maximum voluntary isometric contractions (MVIC), the Biering-Sorensen test and the Pilates Method exercise protocol were performed for 30 minutes. After a 10-minute rest, the Biering-Sorensen test was repeated. Data collection during maximal voluntary isometric contractions and the Biering-Sorensen test were performed using electromyography (EMG).

Maximum voluntary isometric contraction

Two tests of maximum voluntary isometric contraction (MVIC) were performed at different positions, and each test was performed three times, with maintenance of the contraction for four seconds[14]. Here are the descriptions of the postures in which muscle activation was collected:

- Upper trunk flexion: the participant started the test sitting in a chair, with the lower limbs semi-closed. They were asked to try to flex the upper trunk in the sagittal plane, while their chest was attached to the back of the chair by a belt.
- Extension of the trunk: In the prone position, with arms relaxed at the side of the body, the pelvis and lower limbs were fixed by belts on a stretcher, and the trunk remained resting on the stretcher surface. When starting the test, the participant performed extension of the trunk in the sagittal plane. The evaluator offered manual resistance against the movement performed by the participant, applying resistance against the volunteer's scapula[14].

Before data collection, the evaluators instructed the participants to correctly perform the tests and to familiarize themselves with them to achieve proper performance. The sequence of the postures started with trunk flexion, followed by the trunk extension test, and the attempts in which movements occurred were repeated to guarantee an isometric contraction. To avoid muscle fatigue, a one-minute rest interval was given between each contraction[14].

Biering-Sorensen Test

To perform the Biering-Sorensen test, participants were placed prone position on an evaluation bed, with the upper border of the iliac crest bone positioned at the upper border of the litter, and the trunk resting on a removable surface. The lower portion of the trunk was secured by belts attached to the medial regions of the gluteus maximus, femoral biceps and gastrocnemius. Cushions were used under the belts to provide better comfort and stability. At the beginning of the test, the support was removed, and the trunk remained suspended (Figure 1). With the upper limbs crossed in front of the thorax, the participants were asked to maintain the horizontal position of the trunk, maintaining an alignment through the isometric contraction of the spinal erectors (2). The time was recorded, and the test was terminated with voluntary exhaustion.

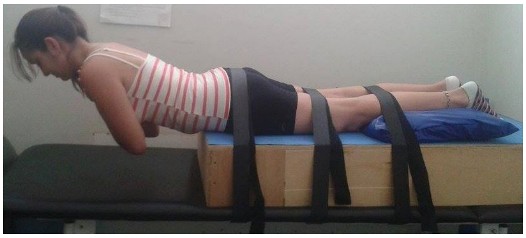


Figure 1. Biering-Sorensen test

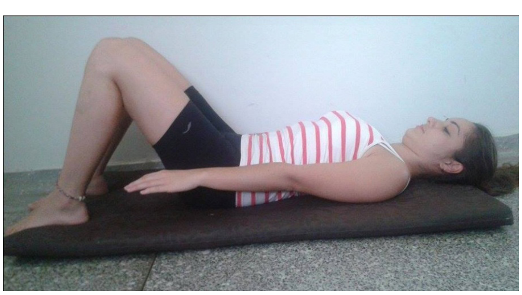
Pilates method exercise protocol

Three exercises of the Pilates method were performed (Hundred level I, One leg stretch level I and One leg circle level I), that work with the primary muscular chain (deep trunk muscles: internal oblique, transverse abdominal and multifidus). During the exercises, the volunteers were instructed to maintain the five key-elements of the Pilates method: centering (submaximal isometric contraction of the deep abdomen muscles), neutral position of the pelvis, alignment of the scapulae (lower trapezius muscle activation), lateral costal breathing, and cervical semi-flexion (activation of the deep cervical flexor muscles).

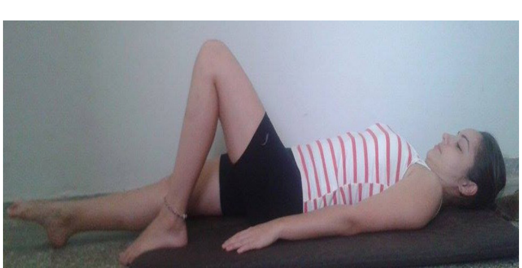
The exercise protocol lasted approximately 30 minutes. There was a one-minute rest between each series and between each exercise. All exercises were carried out on the ground, over an exercise mat. The initial position, common to the three proposed exercises, was: supine position, with the lower limbs semi-closed, feet resting on the mat and upper limbs extended to the side of the body (Figure 2). The exercises are described as follows:

- Hundred, level I: the participant performed rapid movements of shoulders flexion and extension in small amplitude (Figure 2a). Four 25-second sets were performed, totaling 100 repetitions.
- One leg stretch, level I: the participant performed the full unilateral knee extension, sliding the heel over the ground, and flexing it back to the initial position (Figure 2b). Three sets of 15 repetitions were done with each member, alternately, totaling 30 repetitions per set.
- One leg circle, level I: the participant performed unilateral hip and knee flexion, maintaining both joints at 90° flexion, and performed the circumference of the hip clockwise and counterclockwise (Figure 2c). Ten repetitions were made in each direction with both lower limbs, totaling 40 repetitions per set, in a total of 3 sets, with a 1-minute rest between each sequence of 10 repetitions.

a)



b)



c)

Figure 2. a) Hundred exercise, level I; (b) One leg stretch, level II; (c) One leg circle exercise, level I

Electromyography

To obtain electromyographic signals, an electromyograph (EMGSystem, Brazil) was used, programmed with a sampling frequency of 2,000Hz and a total gain of 2,000 times (20 times in the sensor and 100 times more in the equipment).

In the Biering-Sorensen and MVIC test, the electromyographic signals of the internal oblique (IO), iliocostalis lumborum (IL), multifidus (MU) and rectus abdominis (RA) bilateral muscles were collected.

Circular surface electrodes of Ag/AgCl with an area of 1 cm^2 and 2 cm of interelectrode distance were positioned on the muscles: IO, 2 cm inferior and medial to the anterior-superior iliac spines[15]; RA (upper fibers), 3 cm above the navel and 2cm lateral to the midline[16]; MU, at the level of the L5spinous process, over the line formed by the EIPS and the intervertebral space of L1 and L2 (that is, 2 to 3 cm distance from the midline); and IL, one finger of medial width and parallel to the line formed by EIPS and the lowest point of the 12th rib, at the level of the spinous process of L2.

The skin was previously prepared by shaving hairs and applying alcohol on the clean skin, using a gauze to reduce the skin impedance below 5Ω[17].

Statistical analysis

The EMG signal was analyzed in specific routines developed in Matlab environment (Mathworks). The data were processed using a Butterworth bandpass filter of 20-500Hz, the signal was rectified by the whole wave method and smoothed by a 4th order lowpass Butterworth filter, with a cut-off frequency of 6Hz. From the creation of the linear envelope, the percentage of co-contraction was calculated using the following equation:

$$\%\text{Co-contraction} = \frac{2 \times \text{Common Area A\&B} \times 100}{\text{Area A} + \text{Area B}}$$

In this equation, %Co-contraction is the percentage of co-contraction between two antagonist muscles; area A is the smoothed curve of EMG muscle A activity; area B is the smoothed curve of EMG muscle B activity; Common Area between A & B is the common curve of EMG muscle A and muscle B activity[18].

For the statistical analysis, the PASW 18.0 package (SPSS inc.) was used. The normality of the data was verified using the Shapiro-Wilk test. Then, for the comparisons, the ANOVA two-way test was applied for repeated measures, considering group and condition as factors, and, when necessary, the *post hoc Bonferroni* test was applied. The significance level was set at $p<0.05$.

RESULTS

Multivariate analysis showed the main effect of groups (F=12.76 and p=0.008) and conditions (F=16.04 and p=0.005). However, there was no interaction between the factors (F=2.19 and p=0.2).

The group with low back pain presented greater antagonist co-contraction for all ratios evaluated (Figure 3a). The co-concentration between IO/MUr and IO/MUl was, respectively, 41.4% and 32.4% higher in the group with low back pain (p<0.001 and p=0.003). The co-contraction between RA/ILr and RA/ILl was, respectively, 56% and 31.2% higher in the group with low back pain (p=0.004 and p=0.01). The initial condition presented antagonists co-contraction 26.3% higher between IO/MUr (p=0.023) (Figure 3b) and 43.4% between RA/ILr (p=0.03) (Figure 3b).

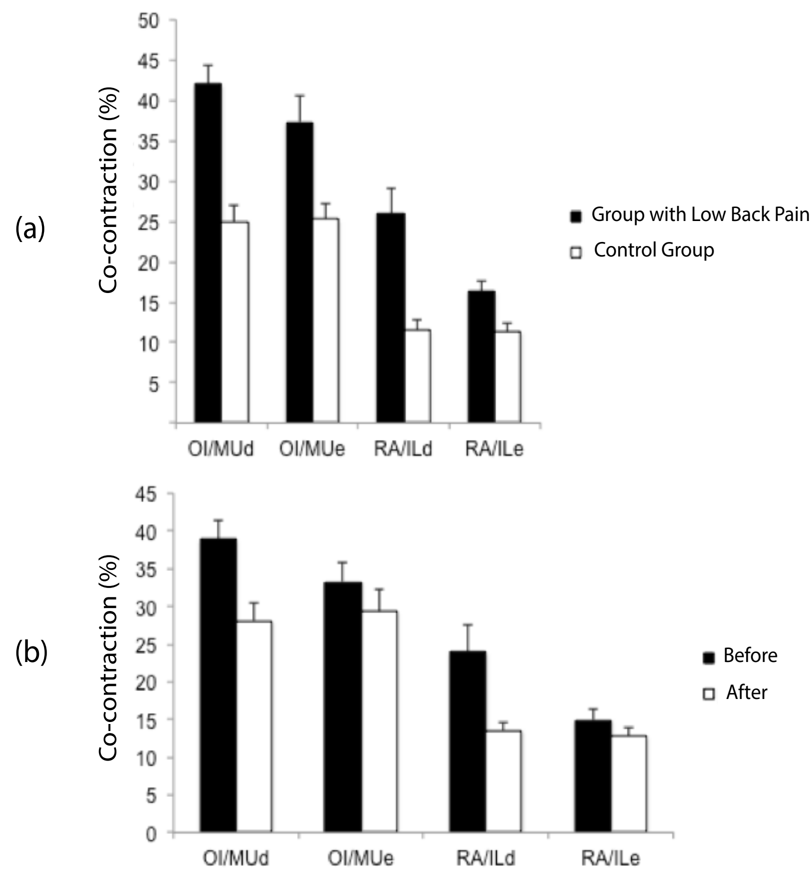


Figure 3. (a) Comparison of antagonist co-contraction between groups; (b) comparing the antagonist co-contraction between the conditions

*p<0.05 refers to the significant difference between the group with low back pain and without low back pain in graph (a), and to the significant difference between before and after training. IO/MUr = co-contraction between internal oblique and right multifidus; IO/MUI = co-contraction between internal oblique and left multifidus; RA /ILr = co-contraction between rectus abdominis and right iliocostalis lumborum; RA/ILI = co-contraction between rectus abdominis and left iliocostalis lumborum

DISCUSSION

The objective of this study was to analyze the immediate effect of a Pilates method exercise session on the co-contraction pattern (agonist/antagonist) of the superficial muscles (iliocostalis lumborum and rectus abdominis) and deep muscles (internal oblique and multifidus) of the trunk in individuals with and without chronic nonspecific low back pain, during the local muscle endurance test (*Biering-Sorensen* test). The main finding of this study was that the co-contraction between IO/MUr and RA/ILl was lower after the exercise session. In addition, the group with low back pain presented greater antagonist co-contraction for both IO/MU and RA/IL. Thus, it is suggested that an exercise session of the Pilates method can reduce the co-contraction of the trunk muscles, which, consequently, can cause less muscular fatigue.

Considering that the Biering-Sorensen test is performed with the trunk extension, for all groups under all conditions, the agonist activation was always greater than the antagonist. Thus, when we observe a high co-contraction ratio, this means that the abdominal muscles activate close to the activation of the paravertebral muscles, which limits the performance in the test by restricting the capacity to generate torque and increasing the energy expenditure. On the other hand, when a reduction in the activation ratio occurs, this means that the paravertebral muscles can activate more motor units, which affects the ability to generate torque, and consequently favors the action of these muscles during the test.

The stability of the lumbar spine is determined by osteo-ligamentary and muscular structures of the trunk. The movements generate loads on the passive structures of the spine and, if unprotected, the lumbar spine becomes vulnerable to injury. The spine stability is maintained by agonist/antagonist co-contraction of the trunk stabilizing muscle, which generates intervertebral stiffness and the increase of the intra-abdominal pressure[19], forming what is called the lumbar stability cylinder, which avoids overload injury.

Bergmark[20] proposed the concept that several muscles act to maintain trunk stability. According to the author, these muscles can be subdivided into two subsystems acting on stability: the local and the global. The local subsystem consists of deep muscles: multifidus, transverse abdomen (TrA) and internal oblique (IO), which have insertion in the lumbar vertebrae and stabilize the vertebral segments. The global subsystem consists of large torque-producing muscles acting on the trunk and spine without being directly connected to it. They are the rectus abdominis (RA), the external oblique (EO) and the iliocostalis lumborum (IL). The co-contraction of these muscles provides stability to the trunk, not being able to directly influence the spine.

In this sense, according to our results, individuals with nonspecific low back pain present greater antagonist co-contraction for both local and global muscles. This may be caused by a compensatory pain mechanism, which increases joint stiffness to reduce the overload imposed by external kinematic disturbances[21]. However, increased joint stiffness can also be damaging to the spine, since it reduces the musculoskeletal system's ability to adapt to overload, reducing steadiness or deformation ability in the system[21].

There are positions in which the co-contraction of deep muscles can be done while maintaining the relaxed global muscles and the spine in a neutral position[22]. Studies indicated that the neutral position of the pelvis favors the recruitment of trunk stabilizing muscles (IO and MU), since in this position there is less action of passive tissues (fascias, ligaments, etc.) to stabilize the spine[23], requiring greater activity of the stabilizing musculature.

In our study, the Biering-Sorensen test, performed with trunk extension – which does not favor the neutral positioning of the pelvis – may have been a limiting factor for us not to find an effect of the exercise protocol in facilitating the co-contraction of the deep trunk muscles (IO/MU). However, the decrease in the co-contraction of the superficial muscles may be related to the change of the trunk muscles recruitment pattern, which favors stability.

In addition, previous studies have found a reduction in the co-contraction of deep muscles[8] and increased co-contraction of superficial trunk muscles[24] in individuals with low back pain. The increased co-contraction of the superficial trunk muscles was considered a functional adaptation induced by change in deep muscular activity, since this mechanism would increase the stability of the trunk and reduce its movement range, making it more rigid and less susceptible to the injuries[24,25]. However, in disagreement, our results demonstrated a reduction in the co-contraction of both superficial and deep trunk muscles.

Pilates exercises aimed at the voluntary request of the deep stabilizers trunk muscles recruitment (internal oblique and multifidus). These exercises are intended to promote a change in neuromuscular programming. This new pattern may have reduced the need of trunk muscles recruitment as a compensatory mechanism to maintain stability of the lumbar region during local muscle endurance test of the spinal erectors. Thus, with reduced muscle co-contraction, the energy expenditure during the task can be reduced, which contributes to the occurrence of less muscle fatigue.

Limitations

This study presents some limitations, such as: the anatomical location of the deep trunk muscles evaluated (lumbar multifidus and internal oblique), making it difficult to capture the electromyographic signal due to the superficial muscles overlap. However, despite the possibility of crosstalk between the IO and transverse abdominis muscles, both have a role in segmental lumbar-pelvic stabilization, just as surface EMG is the only non-invasive way to evaluate the muscle function during a task. Another limitation of this research is the extrapolation of the findings to different populations, such as individuals with specific low back pain (discopathies, etc.), and the fact that, for some comparisons, the n sample may have been underestimated in the calculation. In addition, the Biering-Sorensen test, used to evaluate localized muscular resistance, is a static activity with little functional characteristics, so that reproduction of the co-contraction pattern, found in daily life activities, is limited.

CONCLUSION

A training session with Pilates method exercises was able to reduce co-contraction between the superficial and deep trunk muscles (rectus abdominis/iliocostalis lumborum and internal oblique/multifidus) during the local muscle endurance test of the spinal erectors. This finding demonstrated that Pilates method exercises can have an acute effect on the co-contraction pattern of the trunk muscles in individuals with nonspecific chronic low back pain. Thus, further studies need to be conducted to identify the effects of long-term training with this technique.

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