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Original Article (short paper)

Effectiveness of the Pilates method for individuals with nonspecific low back pain: clinical and electromyographic aspects.

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Abstract — Aims: The aim of this study was to verify the influence of Pilates on muscle activation of lumbar multifidus (LM) and transversus abdominis/internal oblique muscles (TrA/IO) in individuals with nonspecific low back pain. **Methods:** Twelve individuals of both sexes with non-specific low back pain were evaluated before and after a two-month Pilates program in relation to electromyographic activity of LM and TrA/IO, as well as clinical aspects such as pain, flexibility, muscular endurance, quality of life; and Fear-Avoidance Beliefs Questionnaire (in relation to physical and work-related activities. A statistical analysis was performed using a test for independent samples and significance was established at the level of 0.05. **Results:** After eight weeks of Pilates training, there was an improvement in the clinical parameters of pain, flexibility, muscular endurance and disability. The individuals presented lower LM activation (p=0.025), higher trunk extension strength (p=0.005) and an increase in time from onset to peak muscle activation (p=0.02). **Conclusion:** Pilates protocol was effective for clinical improvement and motor behavior in patients with nonspecific low back pain and the parameters assessed showed a large effect size despite the small sample.

Keywords: low back pain; Pilates; electromyography.

Introduction

Musculoskeletal disorders are considered the most prevalent pathologies in developed countries[1]. Among these, low back pain (LBP), which is defined as pain and discomfort, localized below the costal margin and above the inferior gluteal folds, with or without leg pain[2] can be highlighted. The most common form of LBP is nonspecific and occurs when the cause of anatomopathological pain cannot be determined[3]. In Brazil, the LBP prevalence is higher than 50% in adults and 13.1% to 19.8% in adolescents[4,5].

The etiology of LBP is multifactorial and may be associated with factors such as age, sex, smoking, alcoholism, body weight, social class, level of schooling, physical activity and work activities. The literature has highlighted the influence of the imbalance between the function of the extensor and flexor muscles of the trunk in increasing the probability of developing disorders that affect and disrupt the stability of the lumbar spine[6,7]. There is still no consensus in the literature whether the lack of muscle pre-activation is a cause or manifestation of LBP[8], but it is known that the lack of resistance of the trunk muscles may be associated with episodes of this disorder[9]. Muscles that have functional and morphological alterations can be investigated by surface electromyography (EMG)[10]. Its use can provide information about the amount of muscular activity that some exercise or positioning requires, thus facilitating the choice of the most appropriate treatment for each individual[11].

Currently, the use of a lumbar pain classification system, based on the signs and symptoms helps in choosing the most appropriate intervention. Among the classifications for subgrouping patients, the System of Treatment-based Classification (TBC) is able to increase the efficacy of conservative interventions for patients with low back pain[12]. Therapeutic exercises are still considered the most effective resources for treating chronic LBP, although in clinical practice there are varieties of applied exercises[13]. The clinical guideline published by the American College of Physicians (2017) recommended that the first suggestion for patients with chronic low back pain should be nonpharmacologic treatment including exercises and motor control exercise in addition to other therapies[14].

The trunk stabilization exercise has been recommended by most guidelines as a treatment for individuals with LBP who have a coordination deficit of motion[15]. The Pilates Method is an exercise program that is often prescribed for these individuals, since they are used in the activation and strengthening of the stabilizing muscles of the trunk, such as multifidus and abdominal musculature[16]. Pereira, Queiroz, Loss, Amorim, Sacco[17] showed that Pilates is an effective way to allow lumbopelvic stabilizer activation even in the first session in healthy and chronic low back pain individuals[17]. However, only low to moderate-quality evidence showed that Pilates resulted in effects on pain when compared to other physical activity[14,18]. Few high quality evidence clinical trials compared the effects of Pilates to other interventions[19]. Moreover, studies evaluating the improvement of muscle activation of lumbar multifidus (LM) and transversus abdominis/internal oblique muscles (TrA/IO) in individuals with LBP were not found, specifically after an exercise protocol based on the Pilates Method. Since Pilates acts in the contraction of this muscle, it is believed that the method can be used in individuals with lumbar spine instability. Therefore, the present study aimed to verify the influence of a Pilates exercise program on muscle activation of LM and TrA/IO muscles in individuals with nonspecific low back pain.

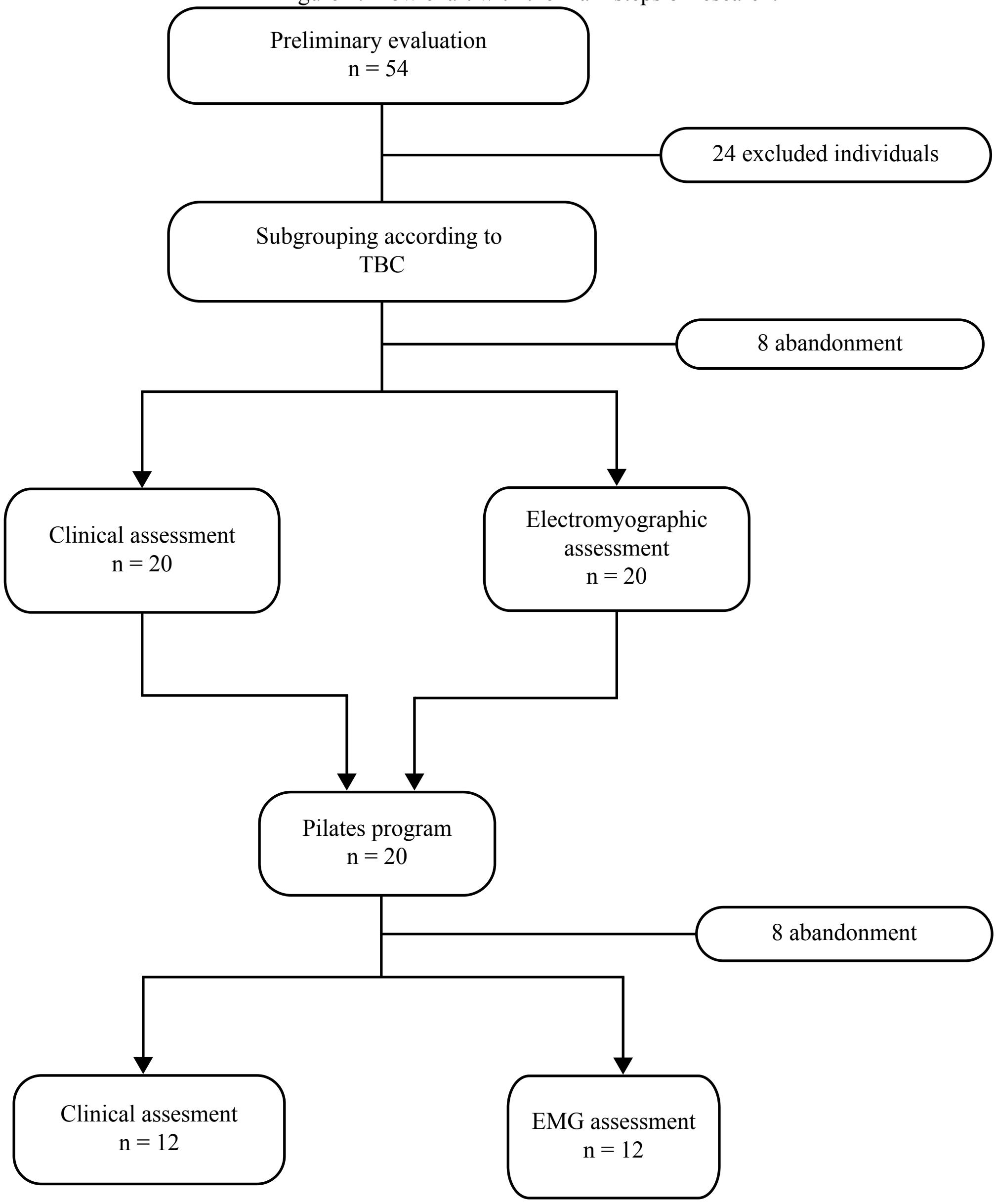
Methods

Subjects

This was a prospective study conducted between February and November 2016, containing a group of individuals with non-specific low back pain followed by two months in which they performed a Pilates program. Subjects were recruited from the inclusion criteria of the TBC[12] subgrouping in which they needed to present symptoms of non-specific low back pain, aged less than or equal to 40 years old. They also need to present at least three of these criteria: a negative Laségue test, aberrant movement (being pain in the accomplishment of the trunk flexion or in the return of the trunk), Fear-Avoidance Beliefs Questionnaire - Work subscale < 19 and positive prone instability test.

The preliminary evaluation performed for the recruitment and subgrouping of the individuals occurred at the Federal University of Santa Catarina (Universidade Federal de Santa Catarina - UFSC) - Campus Araranguá/SC and consisted of an interview of socio-demographic data, anamnesis, and a physical examination. Before any methodological procedure, the participants signed a free and informative consent form and the research was approved by the Research Ethics Committee (N. 1.041.755). Fifty-four previous evaluations were performed and 20 individuals were selected according to the inclusion criteria. On a second pre-scheduled day, the volunteers attended the Laboratory of Evaluation and Rehabilitation of the Locomotor System (Laboratório de Avaliação e Reabilitação do Aparelho Locomotor - LARAL) to perform the electromyographic evaluation and subsequently initiated a Pilates protocol. Among the 20 selected individuals, 8 gave up throughout the protocol due to the times incompatibility, finishing the study with 12 volunteers of both sexes, combined with an average age of 25.41 (± 6.27) years, average weight of 59.41 (± 11.13) kg, average height of 1.63 (± 0.07) meters and a mean pain level presented of 3.83 (± 3.45) on a visual analogue scale. There was only one male volunteer and 75% of the participants were students. The main steps of the research are outlined in the flowchart in Figure 1.

Figure 1. Flow chart with the main steps of research.



Clinical assessment

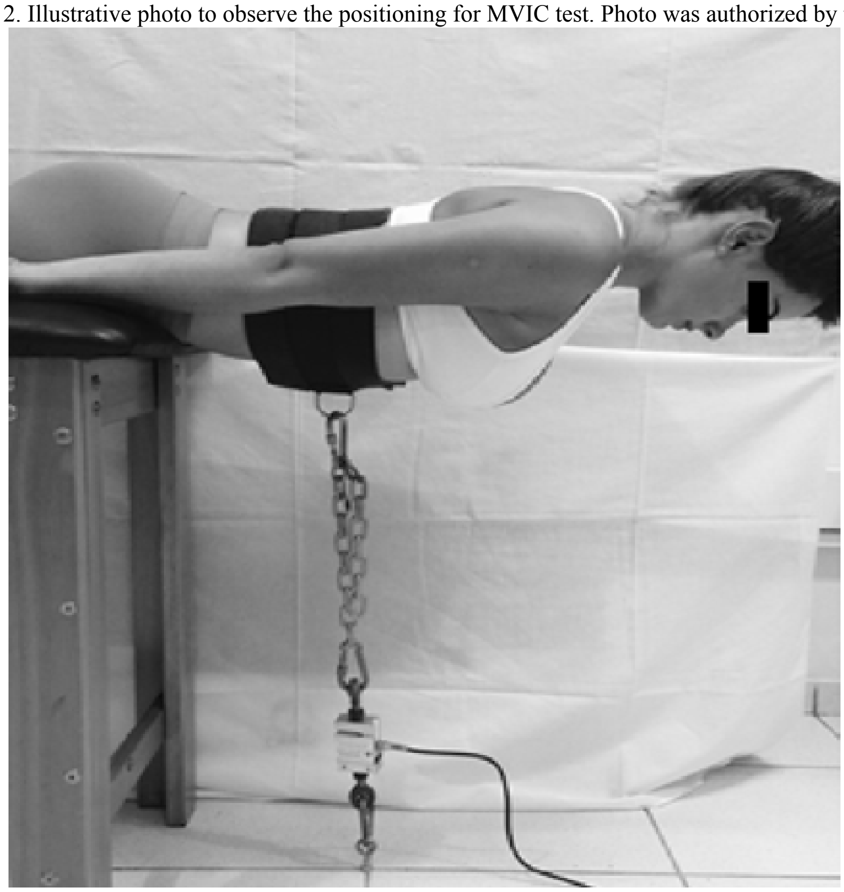
In addition to the tests for inclusion in the subgroup of interest, the tests of Sorensen[20], lateral bridge[20] and distance from the 3rd finger to the ground[21] in the trunk flexion, right and left lateral bending were performed. The Fear Avoidance Beliefs Questionnaire[12] (FABQF: Phys subscale; FABQW: Work subscale), the Oswestry Disability Index[22] (ODI), and the 12-Item Short-Form Health Survey Quality of Life Questionnaire (SF-12) from the Areas of physical health (PCS) and mental health (MCS)[23] were also applied. All evaluations were repeated after the two months of Pilates, respecting a maximum period of one week before and after the protocol for conducting the evaluations and in all meetings before and after the Pilates the visual analog scale of pain (VAS)[24] was conducted.

Electromyographic assessment – instrumentation

The surface EMG signals (sEMG) were obtained using two conditioner modules (Miotec®, Porto Alegre, RS, BRA; model Miotool 400) that utilized a Butterworth type band-pass digital filter with cutoff frequencies of 20 and 500 Hz, an amplifier with a final gain of 1000, and an acquisition frequency of 4000 Hz. To collect sEMG data from the right LM and right TrA/IO, two pairs of bipolar electrodes with Ag/AgCl capture surfaces (Kendall, Mansfield, MA, USA; model Medi-Trace) with diameters of 10 mm were positioned at the sites of the respective muscles with an inter-electrode distance of 20 mm. The LM sensors were positioned in accordance to the SENIAM protocol[25]; and, for the TrA/IO, the sensors were placed about 2 centimeters medial and inferior to the anterior superior iliac crest[26]. A reference electrode was coupled in the styloid process of the ulna on the right forearm. There was a pre-amplifier circuit with a gain of 20 times, a CMRR (Common Mode Rejection Ratio) greater than 80 dB, and an impedance of 1012 X. A Strain Gauge dynamometer was coupled to the electromyography to measure the trunk extension force during the traction exerted by the volunteer. The data were collected using Miotec Suite software (Miotec®, Porto Alegre, RS, BRA).

The sEMG signal was collected at the maximum voluntary isometric contraction (MVIC) at the Sorensen test position, with bands to fix the hips and legs on the hospital bed. The dynamometer was positioned perpendicular to the trunk of the volunteer using an inextensible current. The subject was instructed to perform an MVIC of the trunk while pulling the dynamometer for 6 seconds (Figure 2). After two minutes resting, the sEMG signal was collected during the free trunk extension, in which the volunteer was instructed to leave the resting position, with the upper limbs crossed in the chest and perform a trunk extension to the maximum range of motion and so returning to the initial position with self-controlled speed. Three trials were performed with two-minute rest intervals between them. The same evaluations were conducted before and after two months of performing Pilates exercises.

Figure 2. Illustrative photo to observe the positioning for MVIC test. Photo was authorized by the volunteer.



Pilates program

During a two months period, the volunteers were accompanied while executing a Pilates exercise program. The exercises were from Mat Pilates, supervised by physiotherapy students (in the last 2 semesters before graduation), with increasing difficulty levels throughout the weeks, twice a week, individually and face-to-face mode, within 50 minutes, totaling 16 times. The exercises were: (1) spine stretch forward, (2) saw, (3) cat stretch, (4) roll-up, (5) single leg stretch, (6) single straight stretch, (7) chest lift with rotation, (8) single-leg kick, (9) double-leg kick, (10) pelvic curl, (11) one leg up and down, (12) leg circles, (13) side kick, (14) crisscross, (15) hundred, (16) spine twist supine, (17) swimming, (18) leg pull front, (19) side kick kneeling, (20) leg pull, (21) push-up, and (22) side bend[27]. All the exercises were executed according to traditional Pilates principles: centering, concentration, control, precision, flow, and breathing[28].

Analysis

The extracted sEMG signals of each trial were submitted to the follow analyzes: i) determination of trunk extension force during the MVIC; ii) normalization of multifidus during the free extension test by the MVIC signal, using the two most stable seconds of contraction; iii) determination of the normalized *Root Mean Square* (RMS) of LM during the free trunk extension test; iv) calculation of the time elapsed from the beginning to the maximum activation of the right LM and TrA/IO during the trunk extension test. For all of the analyses, algorithms programmed in MatLab® software were used.

Data from EMG and clinical assessment were compared before and after the Pilates using the unpaired t-test ($\alpha < 0.05$) after the normality confirmation (Shapiro-Wilk test) and the effect size of each comparison was determined by Cohen´s d coefficient (ES-d). Effect sizes were defined as small (ES-d < 0.5), medium ($0.50 \leq d < 0.80$), and large ($d \geq 0.80$)[29].

Results

Clinical assessment showed predominance in the reduction of the symptoms in the prone instability test and of aberrant movement in flexion, in addition to the reduction of pain, increase of the flexibility and muscular endurance. In relation to the prone instability test, initially it was positive in 75% of the volunteers and after the intervention, there was a reduction to 33.33%. The aberrant movement (pain in the accomplishment or in the return of the trunk flexion) was present in 58.33% of the individuals before the Pilates protocol and, after this, there was a decline in these values to 8.33% of the individuals. The pain level, measured through VAS, initially presented a mean of 3.83 (0.99) and after the protocol, there was a significant reduction ($p = 0.01$) to 0.75 (0.50), with large effect size (ES-d = 1.17).

In relation to the tests of flexibility and endurance, a significant difference was observed in the flexion and right lateral bending movements, Sorensen test, and right and left lateral bridge (Table 1). Among the scales used to measure disability, quality of life and beliefs/ fears in relation to work and physical activity, there was an improvement in the scores of all questionnaires. However, there was statistical significance only for disability assessed using the Oswestry Disability Index (Table 1). Except for the SF-12, all of these tests had a large effect size comparing results before and after the intervention.

Concerning muscle activation of lumbar multifidus, there was a significant decrease in the normalized RMS value ($p = 0.025$, ES-d = 0.62) in addition to an increase in trunk extension force ($p = 0.005$, ES-d = 1.33). When analyzing the time elapsed from the beginning to the peak of the activation of the LM, there was a significant increase in this period ($p = 0.023$, ES-d = 0.78) (Table 2).

Table 1. Mean (standard error of measurement) of flexibility, muscle endurance and specific scales before and after the Pilates.

Flexibilily	**Before Pilates**	**After Pilates**	**p-value**
Trunk anterior flexion (cm)	12.6 (2.93)^A	4.87 (1.66)^A	0.03
Right trunk lateral bending (cm)	45.25 (0.96)^B	40.58 (1.34)^B	0.01
Left trunk lateral bending (cm)	45.90 (1.03)	41.33 (1.07)	0.06
Muscle endurance			
Right lateral bridge (s)	14.09 (2.35)^C	30.94 (4.37)^C	0.003
Left lateral bridge (s)	12.99 (2.09)^D	32.38 (5.37)^D	0.003
Sorensen test (s)	36.41 (6.95)^E	74.40 (9.69)^E	0.04
Scales			
FABQF	5.41 (1.57)	1.91 (0.74)	0.05
FABQW	7.41 (1.55)	8.83 (1.90)	0.57
ODI	6.50 (0.94)^F	3.75 (0.79)^F	0.03
SF-12 (PCS)	47.25 (2.33)	52.21 (2.71)	0.18
SF-12 (MCS)	48.40 (3.39)	50.50 (2.61)	0.62

cm: centimeters; s: seconds; A-F: significant difference.

Table 2. Mean (standard error of measurement) of trunk extension force, RMS and time elapsed from beggining to peak of activation of LM.

Lumbar multifidus	Before Pilates	After Pilates	p-value
Force (kgF)	10.06 (1.60)[A]	18.50 (2.15)[A]	0.005
RMS (nu)	0.62 (0.05)[B]	0.48 (0.03)[B]	0.025
Time elapsed from beggining to peak of activation (s)	0.70 (0.18)[C]	1.22 (0.10)[C]	0.02

kgF: kilogram force; RMS: Root Mean Square; nu: normalized unit; A-C: significant difference.

The comparison of the LM and TrA/IO temporal parameters of muscle activity before the Pilates protocol showed a difference in the time from the beginning to the peak of the sEMG signal and in the duration of muscle contraction between the two musculature ($p < 0.05$): the LM reached the peak of activation earlier than the TrA/IO and with a lower period in contraction with medium to large effect size (Table 3). After the Pilates protocol, both muscles presented the same behavior: the LM increased the duration of contraction, in addition to increasing the time to reach the peak of activation ($p > 0.05$), remaining with temporal parameters similar to the TrA/IO (Table 3) but with small effect size (ES-d < 0.40).

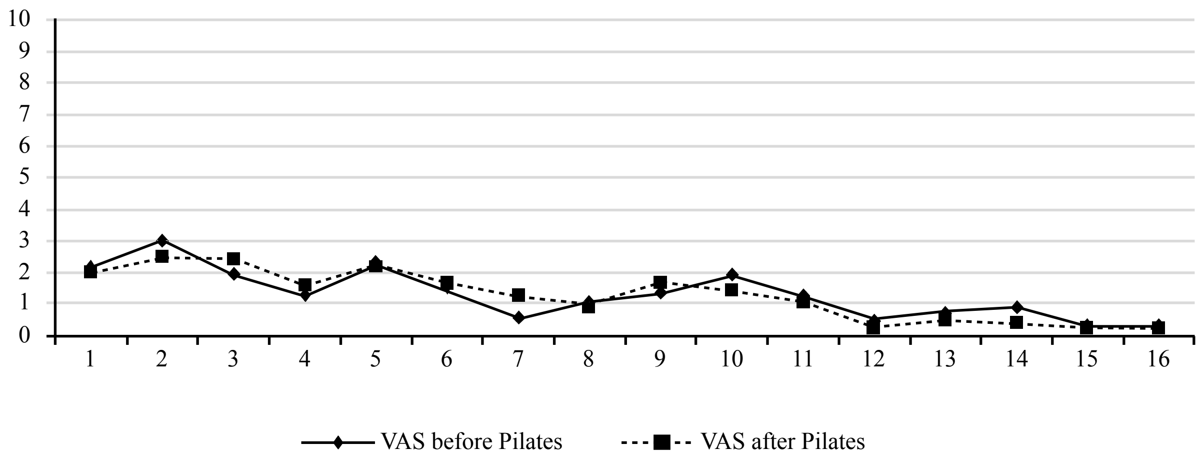
The level of pain through VAS was measured daily before and after the Pilates exercises and during the eight weeks, there was a decrease in these parameters (figure 3).

Table 3. Mean (standard error of measurement) of the comparison between temporal parameters of EMG activity of LM and TrA/IO before and after the Pilates protocol.

EMG data	LM	TrA/IO	p-value
Before Pilates Protocol			
Time elapsed from beggining to peak of activation (s)	0.70 (0.18)[A]	2.15 (0.53)[A]	0.01
Duration of contraction (s)	4.99 (0.31)[B]	6.66 (0.69)[B]	0.03
After Pilates Protocol			
Time elapsed from beggining to peak of activation (s)	1.22 (0.10)	1.79 (0.59)	0.34
Duration of contraction (s)	5.69 (0.38)	6.72 (0.71)	0.21

s: seconds; A, B: significant difference.

Figure 3. Evolution of pain at visual analogue scale (VAS) throughout the 16 days of Pilates.



Discussion

The aim of this study was to evaluate the influence of Pilates on clinical aspects and muscle activation of LM and TrA/IO of individuals with nonspecific low back pain. After eight weeks of a Pilates protocol, there was an improvement in pain, disability, flexibility, motor control, the force of trunk extension, and muscle endurance of the trunk stabilizers.

The results showed that Pilates was effective for the reduction of pain and disability in individuals with non-specific LBP corroborating with similar results found in the literature[7,30,31]. Kofotolis, Kellis, Vlachopoulos, Gouitas, Theodorakis[32] reported that Pilates was more effective than trunk strengthening in increasing the quality of life and decreasing the functional disabilities after an 8-week protocol and the effects were retained for a three-month follow-up[32]. Studies that evaluated the effectiveness of a Pilates protocol compared to general exercises or self-management for eight weeks concluded that the method was more effective in reducing pain, disability, flexibility and balance in individuals with chronic LBP[21,22]. These authors also emphasized the importance of subgrouping these patients in order to create effective programs aimed at the specific mechanisms of pain, acting even more in the reduction of disability[22].

A preliminary study evaluating muscle endurance using the Sorensen test in patients with pain during movement or flexion posture suggested that decreased muscle endurance, increased sitting time, bad posture, decreased flexibility, and that inactivity may contribute to the onset of non-specific low back pain[33]. Similar results were found in our study, in which 58.33% of the individuals had pain in the anterior flexion movement of the trunk, decreased flexibility, and long periods of sitting. Phrompaet, Paungmali, and Pirusan[34] evaluated the flexibility and pelvic stability of healthy individuals before and after a Pilates program of eight weeks and found that there was an increase in these parameters after the intervention, suggesting that the improvement of stability may be due to the improvement of local muscle control, motor learning and physiological response to exercise. Our findings corroborate to these authors because there was an improvement of muscle force and flexibility after the intervention protocol.

Regarding the EMG, the results showed lower muscle activation of multifidus and greater force of trunk extension after the Pilates protocol. This suggests that there was an improvement in motor control and a lower propensity to fatigue because there was a need to recruit fewer motor units to achieve greater force. The literature has demonstrated that people with low back pain show a temporal contraction pattern different from healthy people and similar to healthy but fatigued individuals[35]. It is known that lumbar pain causes inhibition and atrophy of the deep fibers of multifidus, the pathological mechanism of which can be identified in electromyography as an increase in muscle activation and a decrease in fiber conduction velocity[36,37]. For the evaluation of the time elapsed from the beginning to the peak of the EMG signal of the LM, an increase of this period occurred, showing that the activation happened in a smoother and gradual way which indicates better motor control. It is believed that motor control is related to the type of muscular fiber predominant. Motor units composed of type I fibers have more ordered firing characteristics and larger inter-peak periods, and therefore a more synchronous activation. While motor units composed of type II fibers present shorter intervals, frequently present in individuals with low back pain, it can be visualized as an increase in the amplitude of the EMG signal[38].

When the temporal EMG parameters were compared to LM and TrA/IO before the Pilates protocol, the time from onset to peak and the duration of contraction were different. The multifidus had a shorter duration of contraction and reached the peak of activation earlier than the TrA/IO. After the Pilates protocol, both muscles had the same behavior, increasing the duration of contraction of the multifidus and also the time to reach the peak of activation, remaining with the temporal parameters similar to the TrA/IO. Thus, after the intervention, there was a balance of muscular action between LM and TrA/IO suggesting a co-activation of the trunk stabilizing muscles. The postural preparation physiologically occurs before the beginning of the movement and the LM and TrA/IO are responsible for this dynamic stability[26]. The stability of the trunk may be compromised by delayed activation of the musculature of this region[39]. Furthermore, it is not yet known if the lack of pre-activation is a cause or a manifestation of low back pain[8]. By our findings, it can be observed that there was pre-activation of the lumbar musculature in relation to the abdominal musculature determined by the time elapsed from the beginning to the peak of the activation before the treatment protocol; and after treatment, the multifidus started to have the activation together with the abdomen, suggesting that the lack of a previous activation or co- activation of the abdomen may be the cause of LBP. However, the effect-size of the comparison between LM and TrA /IO after Pilates was small, so caution should be taken when extrapolating these data to the population. It is recommended, therefore, that future studies may recruit more individuals so that this comparison can be performed.

Our results allow us to infer that Pilates promoted an improvement in clinical parameters of LBP patients, in addition to a decrease in muscle fatigue of LM. Furthermore, the lack of co-activation of lumbar and abdominal muscles could be reversed with the Pilates protocol, since individuals started to present similar activation between the multifidus and abdomen, regarding the temporal parameters. With the results obtained by this study and with data already reported in the literature, it is suggested that the Pilates treatment is effective for improving motor behavior and clinical parameters in individuals with low back pain who present instability according to the System of Treatment-based Classification of low back pain. Thus, conservative treatment is effective and may decrease costs on pharmacological or the risks of surgical treatment.

The non-blinding of the evaluators and the individuals evaluated in relation to the treatment is considered as a methodological limitation of this study, in addition to possible errors in the collection of information on the variables of interest, since self-administered questionnaires were performed in which individuals could present recent memory bias.

Conclusions

The results allow us to conclude that an exercise protocol using the Pilates method for eight weeks is effective for improving the motor behavior of the trunk stabilizing muscles and for the clinical signs of pain, disability, flexibility, force and muscular endurance in patients with non-specific low back pain. This suggests that the Pilates Method may be indicated for the treatment of these individuals.

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