REVIEW ARTICLE
BASIC SCIENCES/OTHERS
http://dx.doi.org/10.1590/S1808-185120222103262482

THE EFFECT OF PILATES EXERCISES ON MUSCLE ELECTRICAL ACTIVATION IN ADULTS WITH CHRONIC LOW BACK PAIN: A SYSTEMATIC REVIEW

EFEITO DOS EXERCÍCIOS DE PILATES NA ATIVAÇÃO ELÉTRICA MUSCULAR EM ADULTOS COM LOMBALGIA CRÓNICA: REVISÃO SISTEMÁTICA

EL EFECTO DE LOS EJERCICIOS DE PILATES SOBRE LA ACTIVACIÓN ELÉCTRICA MUSCULAR EN ADULTOS CON LUMBALGIA CRÓNICA: REVISIÓN SISTEMÁTICA

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ABSTRACT

Low back pain is one of the most prevalent orthopedic conditions, affecting around 70% to 80% of the world's population at least once during their life times. Surface electromyography is an important tool for assessing the muscle function of the lumbar stabilizers. One of the best treatment options for patients with chronic low back pain (CLBP) is physical exercise, particular lyaerobic exercise and Pilates, as these can reduce short-term pain and disability, and improve balance. This review aims to identify the state of art regarding the benefits of pilates on the population with CLBP, evaluating changes in the muscular activation of the muscles of the lumbar region. Searches were conducted on the following databases: PubMed (Medline), Science Direct, Scopus, Web of Science, Cochrane, Ebsco and Scielo; including gray literature: Google Scholar, Grey Literature, Pro Quest Dissertations & Theses. The inclusion criteria were adults with low back pain for three months or more, with or without referred pain in the lower limbs; studies that used electromyographic variables; studies with a pain assessment measure at two different times; studies with physical exercise performed only using the Pilates method. Applying these criteria, the searches retrieved 439 abstracts. Of these, 44 articles were evaluated for eligibility, and three fulfilled the qualitative and quantitative synthesis criteria. The average methodological quality score on the Downs and Black checklist was 15 out of 28. It was therefore concluded that Pilates is an excellent option for the treatment of non-specific low back pain, promoting health and helping prevent low back pain among asymptomatic individuals. ***Level of evidence II; Systematic Review of Level II or Level I Studies with Discrepant Results.***

Keywords: Low back pain; Electromyography; Pilates training; Physical activity.

RESUMO

A dor lombar é uma das condições ortopédicas mais prevalentes, afetando cerca de 70% a 80% da população mundial pelo menos uma vez na vida. A eletromiografia de superfície é um importante instrumento de avaliação da função muscular dos estabilizadores lombares. Uma das melhores opções de tratamento de pacientes com dor lombar crônica (DLC) é o exercício físico, principalmente exercícios aeróbicos e Pilates, considerando que podem reduzir a dor e a incapacidade a curto prazo e melhorar o equilíbrio. Esta revisão objetivou identificar o estado da arte quanto aos benefícios do pilates para a população com DLC, por meio da avaliação das alterações da ativação muscular dos músculos da região lombar. A pesquisa foi realizada nas seguintes bases de dados: PubMed (Medline), Science Direct, Scopus, Web of Science, Cochrane, Ebsco e Scielo, incluindo também literatura cinzenta: Google Acadêmico, Grey Literature, Pro Quest Dissertations & Theses. Os critérios de inclusão foram adultos com lombalgia há três meses ou mais meses, com ou sem dor referida nos membros inferiores; estudos que que usaram variáveis eletromiográficas; estudos com medida de avaliação da dor em dois momentos distintos; estudos com exercícios físicos realizados apenas com o método Pilates. Com esses critérios, foram identificados 439 resumos. Desse total, 44 artigos foram avaliados quanto à elegibilidade e três satisfizeram os critérios de síntese qualitativa e quantitativa. A pontuação média de qualidade metodológica foi 15 de 28 na lista de verificação Downs e Black. Concluiu-se, portanto, que o Pilates é uma excelente opção no tratamento de dores lombares não específicas, resultando na promoção de saúde e na prevenção desta condição para indivíduos assintomáticos. ***Nível de evidência II; Revisão sistemática de Estudos de Nível II ou Nível I com resultados discrepantes.***

Descritores: *Dor lombar; Eletromiografia; Método Pilates; Atividade física.*

RESUMEN

La lumbalgia es una de las afecciones ortopédicas más prevalentes, que afecta a entre el 70% y 80 % de la población mundial al menos una vez en la vida. Las electromiografía de superficie es una herramienta importante para evaluar la función muscular de los estabilizadores lumbares. Una de las mejores opciones de tratamiento para pacientes con dolor lumbar crónico (DLC) es el ejercicio físico, concretamente

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Received on 03/27/2022 accepted on 06/30/2022
Reviewed by: Dr. Alexandre Fogaça Cristante

los ejercicios aeróbicos y el pilates, ya que pueden reducir el dolor y la discapacidad a corto plazo y mejorar el equilibrio. Esta revisión tuvo como objetivo identificar el estado del arte en cuanto a los beneficios del pilates para la población con DLC, evaluando los cambios en la activación muscular de los músculos de la región lumbar. La investigación se realizó en las siguientes bases de datos: PubMed (Medline), Science Direct, Scopus, Web of Science, Cochrane, Ebsco y Scielo; incluyendo también la literatura gris: Google Scholar, Grey Literature, Pro Quest Dissertations & Theses. Los criterios de inclusión fueron adultos con lumbalgia durante 3 meses o más, con o sin dolor referido en miembros inferiores; estudios que han utilizado variables electromiográficas; estudios con medición de la evaluación del dolor en dos momentos diferentes; estudios con ejercicios físicos realizados sólo con el método Pilates. Con estos criterios, se identificaron 439 resúmenes. De este total, se evaluó la elegibilidad de 44 artículos y 3 cumplieron los criterios de síntesis cualitativa y cuantitativa. La puntuación media de calidad metodológica fue de 15 sobre 28 en la lista de verificación de Downs y Black. Por lo tanto, se concluyó que el Método Pilates es una excelente opción en el tratamiento de la lumbalgia inespecífica, lo que resulta en la promoción de la salud y prevención de este padecimiento para individuos asintomáticos. ***Nivel de evidencia II, Revisión sistemática de Estudios de nivel II o Nivel I con resultados discrepantes.***

Descriptores: *Lumbalgia; Electromiografía; Método Pilates; Actividad física.*

INTRODUCTION

The International Association for The Study of Pain defines pain as an unpleasant sensory and emotional experience associated with actual or potential tissue damage.[1] Pain is often described as the fifth vital sign,[2] along with temperature, heart rate, respiratory rate and blood pressure, despite the impossibility of obtaining precise values with objective measures. Low back pain is not a disease but a symptom, similar to headaches and dizziness, associated with known or unknown diseases.[3-5] Chronic low back pain (CLBP) is characterized by pain or discomfort in the region between the costal margins and the lower gluteal fold, with or without referred pain in the lower limbs, in the absence of severe spinal pathology or nerve root involvement,[3] and lasting for more than twelve weeks.[6,7] Low back pain can be divided into three categories: specific spine pathology, radicular pain and non-specific low back pain (NSLBP). The latter is the most common form when the pathological etiology cannot be defined. Low back pain is one of the most prevalent orthopedic conditions, affecting about 70% to 80% of the world's population at least once in their lifetimes.[8,9] Among those who experience low back pain, 10% to 40% of individuals develop CLBP,[10] resulting in absenteeism from work and limitations on professional performance[11] and daily activities. However, despite various studies on the subject, the precise relationship between the level of muscle activity and NSLBP remains unclear.[12–14]

The lumbar region is very muscular, comprising muscles in several deep layers, which makes it difficult to assess the corestabilizing muscles. Techniques related to surface electromyography (sEMG) have been proposed as an important instrument for evaluate the muscle function of the lumbar stabilizers,[15] enabling assessment of muscle imbalances in order to identify the cause of pain in the lumbar spine.[3] In this regard, Chiou *et al*.,[16] reported that in patients with low back pain assessed by sEMG, the characteristics of myoelectric activity of the muscles for the spinal cord differed from those of healthy individuals.

According to Oliveira[17] and Campos,[18] one of the best treatment options for patients with CLBP is currently physical exercise, particularly aerobic exercise and Pilates,[17] as these can reduce pain and disability in the short and long terms[19] and improve balance. The Pilates method comprises around five hundred exercises inspired by gymnastics, yoga and ballet.[20] It is governed by six basic principles: centralization, concentration, control, precision, fluidity of movement and breathing,[17,21,22] leading to exercises that are performed in a controlled and fluid way. Despite its different forms, the method is prescribed as a treatment for patients with CLBP because it includes exercises to promote flexibility, strength and stability, resulting in greater control of movements,[17,23] stretching shortened muscles, and strengthening weak muscles, in a balanced way.[24]

Considering the importance of studying the Pilates Method in patients with CLBP,[25] and it seffects on electrical activation,[3] it is pertinent to analyze and synthesize the methodologies, and results achieved with the intervention of the Pilates Method in adults with CLBP, in order to understand this subject more deeply and, if possible, find clues for more appropriate intervention. Therefore, this systematic review aimed to analyze and compare the effect of Pilates on muscle electrical activation in adults with CLBP.

METHODS

Protocol and Eligibility Criteria

This systematic review was carried out according to the PRISMA guidelines.[26] The question was developed following the acronym PICOS, where P, population, was defined as adults between the ages of 18 and 65; I, intervention,represents the Pilates Method; C, comparator, was defined such as the comparison of pain levels before and after the intervention; O, outcomes,represents the electromyographic variables and subjective pain scales; and S, study design, represents the experimental or quasi-experimental design with two evaluation points of the variables.

The eligibility criteria were also defined according to the PICOS,[26] and are similar to those of other reviews on related themes.[12,27–29] The inclusion criteria were: I) adult population[30] with low back pain for three month sor longer,[12,31] with or without referred pain in the lower limbs;[27] II) studies that use electromyographic variables to measure muscle electrical activity,[12,32] III) studies that measure pain at two different time points (i.e., pre- and post-intervention); IV) the use of Pilates as the sole form of physical exercise. The exclusion criteria were: I) studies on a population with low back pain diagnosed with underlying pathologies, with or without prior surgical intervention; II) studies that did not focus specifically on the lumbar spine,[33] and III) descriptive studies.

Search Strategy

The literature search was carried out between January 10 and March 15, 2020, on the following databases: PubMed (Medline), Science Direct, Scopus, Web of Science, Cochrane, Ebsco and Scielo; including grey literature: Google Scholar, Grey Literature, Pro Quest Dissertations & Theses. These databases were selected because they represent a wide spectrum of disciplines that carry out research on the themes of the present study.[12,27–29] No cut-off dates or language limitations were applied. To maximize the spectrum of research, the databases were searched in English, using the following keywords: (((lowbackpain) OR (chroniclowbackpain) OR (LBP) OR (nonspecificlowbackpain)) AND ((electromyography) OR (EMG) OR (sEMG) AND Pilates).

Study Selection

For study selection the reference management software Zotero 5.0.96 was used. First, one of the reviewers removed duplicates and screened the titles to see whether the studies matched the eligibility criteria. Next, two reviewers independently screened the abstracts and the full articles. Any disagreements were resolved through discussion, and with a help of a third reviewer when needed. The article selection process is represented by the flow chart shown in Figure 1.

Data extraction and summary measures

The data were extracted by one reviewer and confirmed by another, independently of the first. The following information was extracted: I) authors, II) year of publication, III) sample characteristic, IV) intervention, V) characteristics of the exercises, VI) evaluation methods and variables, VII) main results, and VIII) conclusions. Where the articles did not contain all the required information or were unclear, the authors were contacted for more details.

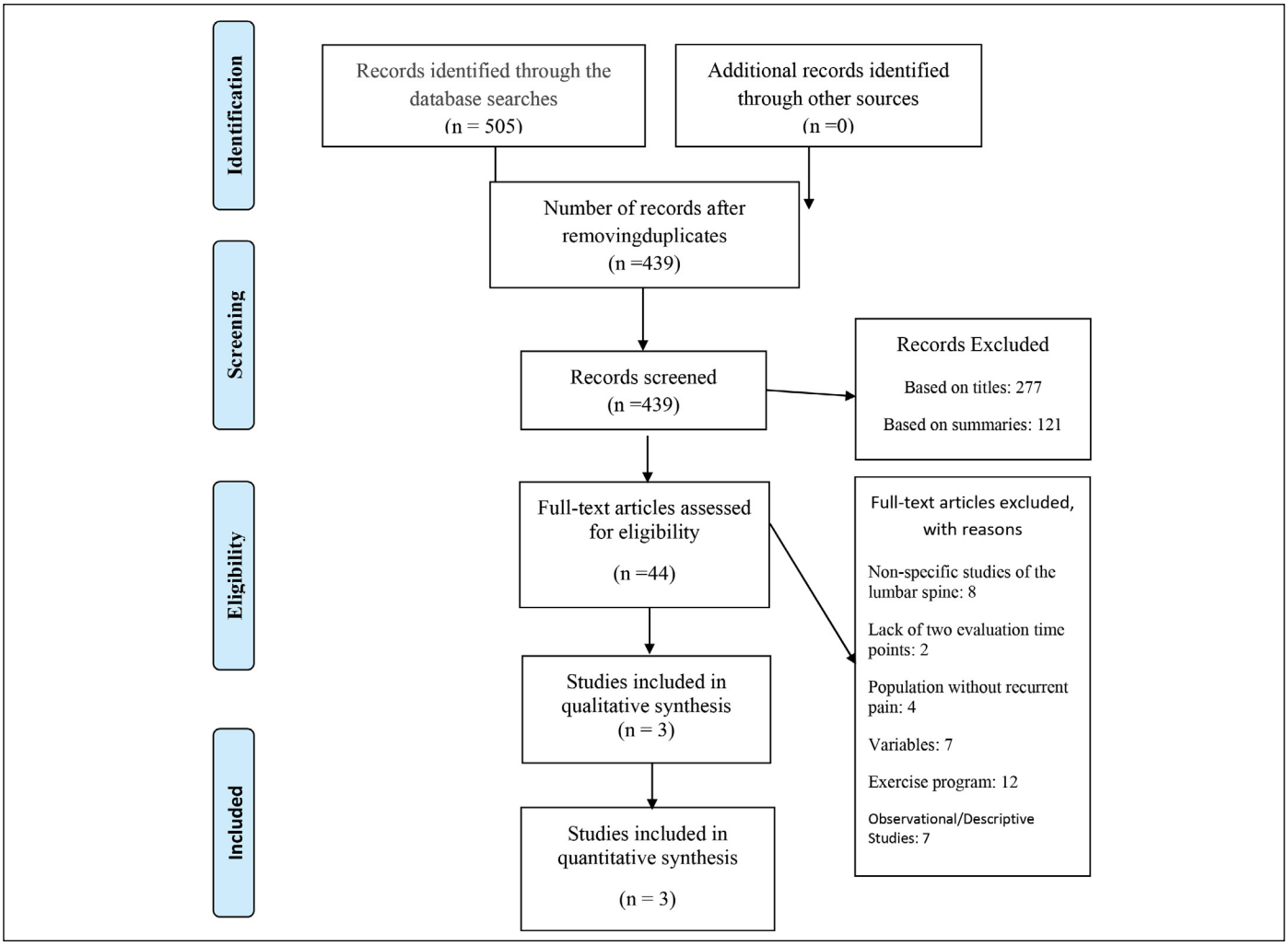

Figure 1. Search strategy flow chart.

The extracted data were presented and synthetized in tables, taking the difference in mean pre- and pos-intervention as the main summary measures.

Quality Evaluation

The quality evaluation was performed by two independent reviewers, and any disagreements were solved with the help of a third reviewer. The previously validated modified Downs & Black Scale, which assesses internal and external validity and power (bias of individual and across studies), was applied, resulting in quality scores based on the checklist: 26-28 (excellent), 20-25 (good), 15-19 (fair), and ≤14 (poor). The denominator for the quality index varied depending on the study design (observational vs. randomized), and was calculated by adding the scores for each component and dividing theseby the totalpossible score.[34]

RESULTS

Study selection

The initial searchfound 505 articles, from which 43 studies were considered potentially relevant and were retrieved for detailed analysis. After a complete reading of the 43 articles, 40 were excluded. At the end of this process, three articles[3,25,35] met the eligibility criteria (Figure 1).

Study Characteristics

All the studies included a sample of male and female patients instructed to perform Pilates exercises. Two of the studies[3,36] also included a control group. The sample sizes in the experimental group ranged from 12 to 19.The Pilates Method was performed in individual face-to-face sessions lasting 50 minutes, 2 to 3 times a week,for around 2 to 4 months.[3,36,37] All the studies used biomechanical instruments, including electromyography and dynamometer,[3,36,37] pain scales and belief questionnaires (Table 1).

The methodological quality of the articles included resulted in a fair assessment with an scoreof 15.[38]

Pain Intensity

All the studies assessed pain intensity using the validated Visual Analog Scale for Pain (VAS) scale. The VAS is a continuous scale, consisting of a horizontal or vertical line, 10 centimeters long, with "No Pain" at one end and "Maximum Pain" at the other. The patient draws a perpendicular mark on the line at the point that represents the intensity of their pain and, subsequently,the distance between the beginning of the line (which corresponds to zero) and the placed marked is measured in centimetersto givea numerical score.

All the studies verified a decrease in pain level after intervention, but this decrease was only significant in the studies by Alves and collaborators[3] and Machado et al.,[37] with differences of 3.28 and 3.08 points, respectively, between the two collection time points (Table 2). In the study by Knox *et al.,*[36] there was a reduction of 1.9 points, though this was not considered significant.

Muscle Activity

All the included studies analyzed muscle electrical activity directly in the abdominal and lumbar muscles[3,25,35] using sEMG.

Table 1. Summary of the Articles studied.

Author (year)	Participants (nº) Age (years) = Mean (SD)	Intervention	Exercise (frequency; duration)	Variables - Evaluation Instrument	Results	Conclusions
Machado P.M. et al.[37]	Experimental Group (CLBO)" antes da apresentação do N N = 12; both sexes; Age: 25.41 (± 6.27) years; Pain level: 3.83 (± 3.45)	Pilates	Individual and face-to-face exercises, 50-minute sessions twice a week for two months.	sEMG (Lumbar Multifídus, Transverse Abdominal and Internal Oblique) -electromyography; muscular endurance; strength - dynamometer flexibility; quality of life; pain level (VAS); fear avoidance beliefs questionnaire (FABQF)	After intervention: less activation in the multifidus (p = 0.025), greater trunk extension strength (p = 0.005) and increased time from start to peak muscle activation (p = 0.02).	The Pilates method after 8 weeks proved to be effective for: improving the motor behavior of the stabilizing muscles of the trunk; clinical signs of pain; inability; flexibility; muscle strength and endurance in patients with nonspecific low back pain.
Alves M. C. et al.[3]	Experimental Group (non-specific low back pain) N = 19; 6 men and 13 women Age: 26.94 (± 1.62) years Control Group (healthy) N = 16; 2 men and 14 women Age: 28.75 (± 1.59) years	Pilates Pilates	Participants had individual and in-person sessions of 50 to 60 minutes, twice a week, for eight weeks (16 sessions in total). They did not take any drugs.	sEMG (Lumbar Multifídus, Transverse Abdominal and Internal Oblique) -electromyography; Muscle resistance extensors of the lumbar spine (Sorensen test) and the lumbar square (tests of the right and left lateral bridge) - dynamometer The Fear Avoidance Beliefs Questionnaire (FABQF); the OswestryDisability Index (ODI); pain level (VAS) only forparticipants in the experimental group	Significant differences only for the duration of the right lumbar extensor and onset before and after intervention; and muscle endurance (p = 0.04); and for pain level 3.78 (0.66) to 0.50 (0.34) (p = 0.01). For the other parameters, the effects of the intervention were similar in both groups.	After the Pilates protocol, individuals with low back pain had decreased pain and lower disability scores, as well as fewer fears and beliefs related to pain in the practice of physical activity and improved flexibility, endurance and muscle strength.
Knox M.F. et al.[36]	Experimental Group (CLBP) N=12 Control Group (CLBP) N = 12	Pilates Everyday activities	Participants in the experimental group performed three exercise sessions / week for 8 weeks.	sEMG (rectus abdominis, transverse, internal oblique and spinal erector) -electromyography; compensatory postural adjustments, anticipation - unilateral trunk flexion; pain level (VAS); Oswestry Disability Index (ODI)	Reduction in the disability scale score in the experimental group (p = 0.001). Compared to the initial moment, the onset of activation of the spinal erector later changed in the experimental group (p = 0.009). Onset TrA/IO was different on each side (p <0.001), with early onset for TrA/IO compared between the same side. The amplitude of TrA/IO in compensatory adjustments increased only in the experimental group (p = 0.012).	8 weeks of exercise can improve motor control in people with CLBP, highlighted by the increase in compensatory postural adjustments in the transversus abdominis and internal oblique. Muscular adaptation for compensatory postural adjustments promoted a pattern of activity similar to that of healthy individuals.

Table 2. Pain intensity before and after application of the Pilates Method, and respective measurement scale.

Study	Pre-Pain Level M ± SD	Post- Pain Level M ± SD	Significance Level	Scale
Alves M. C. et al.[3]	3.78 ± 0.66	0.50 ± 0.34	p ≤ 0.01	VAS
Machado P.M. et al.[37]	3.83 ± 0.99	0.75 ± 0.50	p ≤ 0.01	VAS
Knox M.F. et al.[36]	4.87 ± 2.03	2.97 ± 2.30	----	VAS

Note: VAS: Visual Analogue Scale; ODI: Oswestry Disability Index; FABQF: The Fear Avoidance Beliefs Questionnaire.

The electromyographic variables studied were used to quantitatively evaluate the signals through the temporal structure (onset and duration), and the amplitude and root mean square (RMS). Determination of the times of occurrence of the most important phenomena, such as the start of activations or the duration of events and the amount that expresses the level of signal activity, that is, quantification of the signal intensity. The study by Alves *et al.*[3] revealed significant differences in onset and root mean square in the right lumbar extensor, while the remaining studies did not reveal any significant changes in the electromyographic variables studied. The EMG values obtained in pre- and post-intervention are presented in Table 3.

In the study by Alves *et al.,*[3] significant differences were found in the onset and mean square root after applying the Pilates Method. Machado *et al.*[37] found a decrease in the root mean square (p=0.025), with an average effect size (ES=0.62), and an increase in the lumbar multifidus onset (p=0.023), with an average effect size (ES=0.78). Comparing the lumbar multifidus with the abdominal/internal oblique transversus, both demonstrated the same behavior: the contraction time of the multifidus was increased, as well as the time to reach the peak of activation (p>0.05), with similar temporal parameters for the abdominal/internal oblique transverse, though with a small effect size (ES<0.40).

Knox *et al.*[36] applied a rapid arm flexion as an assessment exercise, in order to determine the amplitude of the muscles during pre-activation (PPA), the adjustment during the flexion movement of the right arm (CPAs1) and after flexion (CPAs2). Throughout the analysis, the right side was considered as ipsi and the left side as contra, to facilitate the correct designation ofthe studied musculature. No differences were detected in the amplitude of the abdominal/internal oblique transverse on the left side at CPA1. However, on the right side, greater amplitudes were found in both moments (pre- and post-intervention). Significant differences were detected in the exercise group, with an increase in the amplitude of the transverse abdominal/internal oblique ipsi at CPA2 (p≤0.05), and in the amplitude of the ipsi spinal erector at PPA (p≤0.05).

In order to relate and increase the relevance between data, the muscular electrical activity was collected from the electromyography,

and muscular resistance and strength through a dynamometer. Muscle endurance data were collected in seconds, during the lateral bridge on both sides and during the Sorensen test. The assessment of strength in trunk extension was determined using the maximum voluntary isometric contraction test (MVIC), with a duration ofsix seconds.

Table 4 shows the values obtained for resistance and muscle strength of the extensor muscles of the spine in the study by Machado et al.[37] There was a significant difference in the muscle endurance parameter both in the bridge lateral, on both sides, either in the Sorensen test, and also an increase in trunk extension force ($p=0.005$) with great effect size (ET=1.33), according to the study methodology.

According to Alves et al.,[3] after the Pilates intervention, there was a significant improvement in muscle endurance and trunk extension strength ($p\leq0.01$).

The exercises performed in the analyzed articles involved different positions (4 support, sitting, side, supine, ventral decubitus) and functions (mobility, stability, abdominal strength).

DISCUSSION OF THE RESULTS

This work aimed to determine the effect of the Pilates Method on muscle electrical activation in adults with chronic low back pain (CLBP). Two of the studies analyzed indicate that the Pilates Method was effective in reducing low back pain in people with this pathology. One of the studies found no significant differences in pain intensity. The average pain in the studies analyzed was 4.16 before performing the Pilates exercises, and 1.41 afterwards, considering a pain scale of 0 and 10. This represents a significant improvementof 66% in pain perception.

The results of this review are consistent with those of previous articles.[39,40] In a descriptive study that analyzed the state of the art of the relations between Pilates and CLBP, Eliks et al.[41] found a positive effect of Pilates on reducing pain and improving functionality in patients with NSLBP after three months, an effect that is especially beneficial if no other modality is used simultaneously. However, due to the ambiguous results of previous research, it is not possible to determine the superiority of Pilates performed on a mat on the floor, or using special devices,in patients with NSLBP. The benefits of Pilates in improving activation of the core muscles of the trunk, andas an important component to achieve positive results in patients with NSLBP, are widely publicized in the literature.[39]

Muscle Activity

Impairment of spine muscle function, as a consequence of muscle fatigue for example, imposes excessive overloads on the passive elements of the lumbar spine, promoting plastic deformation of these structures, which are sensitive to distension. This leads to low back pain.[42] For this reason, the behavior of muscle fatigue (defined as a reduction in the capacity of the neuromuscular system

Table 3. Synthesis of the results of the electromyographic variables before and after the Pilates Method intervention.

Study	Exercises	Muscle	Variable	Pre Pilates (M+- SD)	Pos Pilates (M+- SD)	Significance Level
Alves M. C. et al.[3]	Trunk Extension	RLE	Onset Duration RMS	1.03(0.18) 6.00(0.32) 0.61(0.03)	1.48(0.11) 5.86(0.29) 0.51(0.02)	p≤0.01 ---- p=003
		RTrA/IO	Onset Duration RMS	2.18(0.44) 7.25(0.45) 0.12(0.00)	1.63(0.36) 6.87(0.41) 0.12(0.00)	---- ---- ----
Machado PM. et al.[37]	Trunk Extension	LM	Onset Duration RMS	0.70(0.18) 4.99(0.31) 0.62(0.05)	1.22(0.10) 5.69(0.38) 0.48(0.03)	p=0.02 ---- p=0.025
		TrA/IO	Onset Duration	2.15(0.53) 6.66(0.69)	1.79(0.59) 6.72(0.71)	---- ----
Knox MF. et al.[36]	PPAs	RA	Amplitude	3.12(1.58)	2.67(1.63)	----
		TrA/IO Ipsi	Amplitude	1.73(0.92)	1.14(1.33)	p<0.001
		TrA/IO Contra	Amplitude	4.24(1.62)	3.79(1.52)	----
		ES Ipsi	Amplitude	9.45(7.80)	8.01(3.08)	p<0.05
		ES Contra	Amplitude	16.40(7.52)	14.26(11.00)	----
	CPAs 1	RA	Amplitude	6.04(2.02)	5.36(2.58)	----
		TrA/IOIpsi	Amplitude	6.95(2.45)	8.56(4.98)	p=0.012
		TrA/IOContra	Amplitude	3.70(0.95)	3.58(1.37)	----
		ES	Amplitude	13.26(8.38)	11.78(4.78)	----
	CPAs 2	RA	Amplitude	8.49(6.57)	8.01(8.73)	---
		TrA/IOIpsi	Amplitude	5.21(2.10)	8.63(6.49)	p≤0.05
		TrA/IOContra	Amplitude	5.07(1.70)	4.60(1.39)	---
		ES Ipsi	Amplitude	12.70(4.42)	12.59(8.93)	----
		ES Contra	Amplitude	6.39(2.74)	7.94(7.17)	----

Note: RLE: Right Lumbar Extensor; RTrA/IO: Right abdominal / internal oblique section; LM: Lumbar Multifidus; RA:Rectus Abdominis;TrA/IO: Transverse Abdominal/ Internal Oblique; ES: Spinal erector; Onset and Duration - seconds; RMS - normalized unit (naked); Amplitude: millivolt (mV); PPA: pre-postural activation; CPAs1: adjustment during right arm flexion; CPAs2: adjust immediately after flexing the right arm.

Table 4. Synthesis of the results forstrength and endurance pre- and post-Pilates.

Study	Exercise	Muscle	Variable	Pre Pilates (M+- SD)	Pos Pilates (M+- SD)	Significance Level
Alves M. C. et al.[3]	Trunk Extension –MVIC	RLE	Force	14.09(2.93)	24.28(2.53)	p≤0.01
	Right side bridge		Resistance	23.62(4.44)	37.77(5.00)	p=0.04
	Left side bridge		Resistance	23.07(5.03)	36.64(4.23)	p=0.04
	Sorensen Test		Resistance	44.46(6.11)	87.64(8.29)	p≤0.01
Machado P.M. et al.[37]	Trunk Extension –MVIC	LM	Force	10.06(1.60)	18.50(2.15)	p=0.005
	Right side bridge		Resistance	14.09(2.35)	30.94(4.37)	p=0.003
	Left side bridge		Resistance	12.99(2.09)	32.38(5.37)	p=0.003
	Sorensen Test		Resistance	36.41(6.95)	74.40(9.69)	p=0.04

Note: RLE: Right Lumbar Extensor; LM: lumbar multifidus; Resistance and Sorensen Test - seconds; Force - kilogram force.

to generate spinal muscle strength), has been commonly studied to better understand its relationship with overload in this body segment. Therefore, it is important to analyze the electromyographic activity of these muscles on muscle fatigue, in order to understand the effect of submaximal muscle contractions, which is the effect of the Pilates Method on muscle electrical activation in adults with CLBP, focusing on the muscles necessary for activities of daily living.[43]

Based on the studies included in this review, it was inferred that the use of the Pilates method resulted in increased strength of the trunk extensors, and increased resistance, in seconds, in the Sorensen Test and of the Lateral Bridge on both sides. This suggests an increase in muscle strength, and greater capacity of the muscle to perform the exercises. On the other hand, the levels of electrical activation were decreased (RMS) after the intervention, the activation time increased which represents greater muscle efficiency, more time in contraction and lesser magnitude of activation. Barbosa & Gonçalves[43] report that several studies were performed using the Sorensen Test, with similar results, evidencing a direct relationship between the quality of isometric resistance of the lumbar muscles and isometric resistance time. Based ont hese results, it is suggested that fatigue of the spinal extensor muscles may represent a risk factor for the development of low back pain.

The Pilates exercises are mostly performed lying down, which decreases impacts on the body's supporting joints in the standing position, particularly the spine, allowing recovery of the muscle, joint and ligament structures, particularly in the region of the lumbar sacrum.[44] The main functions of the muscles are to enable mobility or stability of the skeletal apparatus, maintaining as a focus the protection of their structures. These muscular functions are normally related to the superficial muscles, as mobilizers, and to the coremuscles, as stabilizers. In the lower trunk region, both the coreand the surface muscles assume a stabilizing function, which in Pilates, form the powerhouse (trunk flexors, trunk extensors, thigh extensors, thigh flexors, pelvic floor).[22] This powerhouse is considered the physical center of the body, from which all movements of this method must originate, as well as the group of muscles of the trunk that surround the spine and the organs, which work together to provide stability to the spine vertebral system, respecting the principle of centralization.[45]

The stability of the lumbar spine depends a lot on the structures that surround it, and on the muscle tone and the ability to activate and deactivate (motor patterns in steady state) the muscles of these structures. On the other hand, mobility is associated with joint movement; joint kinematics, before being limited by the surrounding structures, such as tendons, ligaments and muscles.[46]

Pilates exercise shave three main effects on the powerhouse: they improve the posture of the pelvis, resulting in postural changes in the lumbar spine; they work directly on the musculoskeletal structure of the spine, enhancing strengthening and stretching; and they affect the structural integrity or cavity tone abdominal-pelvic muscles as a whole.[22] The Pilates method contains more than five hundred exercises, performed in different body positions (standing, on the hands and knees, seated, lying on the side, lying on the back, and lying on the front). The exercises lying on the front focus on improving strength, muscle endurance and correct activation of the spine extensors, promoting the use of spine extensors to produce or maintain spine hyperextension. The abdominal muscles act as stabilizers, reducing potentially harmful forces supported by the lumbar spine. This use of spinal extension is vital for maintaining muscle balance (anteriorly balanced standing position and posteriorly if it causes joint and postural misalignments), asmany Pilates exercises emphasize spine flexion. In addition, increasing the strength and resistance of the spinal extensors can prevent certain spinal injuries, as well as osteoporosis and postural problems.[47] But hyperextension of the spine is a common mechanism of lower back injury, therefore, the correct technique, and careful progression from less to more demanding exercises, are essential to ensurethe potential benefits and reduce the risks.

Asymmetric muscle development results in a loss of harmony and flexibility. During growth, the human body suffers postural imbalances as a result of the lack of a uniform development of all the muscles. Exercising the muscles solely through mechanical daily movements and inadequate postures can result in poor postural habits and spinal problems. Disorders of the lumbar spine are directly related to the inability to stabilize the spine, which can be caused by an imbalance in the functions of the extensor and flexor muscles of the trunk.

Muscolino & Cipriani[22] report that including exercises focused on strengthening the muscles involved in flexion and extension of the trunk in programs of pain prevention and rehabilitation in the lumbar spine region, the search for muscle rebalancing and biomechanical correction is the great challenge for patients with CLBP with Physical Exercise being the safest and most effective way to improve flexibility, strength and muscle function, as well as reducing low back pain, it is important both in the prevention of low back pain and in the rehabilitation of these patients.The exercises used by Alves[3] and Machado[37]are mostly performed lying on the back, and mainly focus on developing the stabilizing function of the flexor muscles of the spine, which is contradictory to the existing literature[22,47] on anterior/posterior muscle balance.

It is difficult to make a definitive and pragmatic recommendation regarding Pilates exercises for patients with NSLBP, due to the a variation in the exercises used in the studies, the duration of the exercise programs, the progression criteria, the muscles activated, and the type of feedback used during the interventions.

The results of the analyzed studies must be interpreted with caution due to the great heterogeneity of electrical muscular activity, the use of different evaluation exercises, and the evaluation of different muscles. The results of this review were based on data of fair quality regarding the Downs and Black quality scale. As electromyography and Pilates are continually evolving areas of study in relation to rehabilitation of injuries and physical exercise, there is a huge gap in the literature that links the two areas. Additional research is needed to verify the positive effects of the Pilates Method over time and to determine its variables, such as mode, intensity, frequency, duration, and time. It is also important to the prescribed exercises with clinical characteristics in the treatment of a subset of patients or individuals with the results of electromyographic evaluations of the injured/affected muscles.

CONCLUSION

Considering the results and discussions presented, it is demonstrated that the Pilates method appears to be an excellent option for the treatment of non-specific[37] and chronic low back pain promoting health and helping to prevent low back pain in asymptomatic individuals. This result is probably due to its easy execution and its ability to strengthen the core muscles. However, although the relationship between Pilates and pain reduction is consistent, further research is needed.

In future studies, greater emphasis should be placed on muscle balance when prescribing exercises, and the respective muscle functions, in order to provide an identical stimulus in the different muscle structures, respecting their motor actions.

All authors declare no potential conflict of interest related to this article.

CONTRIBUTIONS OF THE AUTHORS: Each author made significant individual contributions to this manuscript. CIGR: Conceptualization, Investigation, Formal analysis, Writing - Original Draft, Visualization; CIAM: Conceptualization, Methodology, Writing - Review & Editing, Visualization; JFCC: Conceptualization, Investigation, Formal analysis, Visualization; AMVVB: Writing - Review & Editing,Visualization; MACB: Conceptualization,Visualization, Writing - Review & Editing, Supervision.

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