UNIVERSIDADE ESTADUAL DE CAMPINAS
FACULDADE DE ODONTOLOGIA DE PIRACICABA

ANA CAROLINA PANHAN

AVALIAÇÃO DINAMOMÉTRICA E ELETROMIOGRÁFICA DOS MÚSCULOS DO CORE EM PRATICANTES E NÃO PRATICANTES DE PILATES

DINAMOMETRIC AND ELECTROMYOGRAFIC EVALUATION OF CORE MUSCLES IN PILATES PRACTITIONERS AND NON-PRACTITIONERS

Piracicaba
2020

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DYNAMOMETRIC AND ELECTROMYOGRAPHIC EVALUATION OF CORE MUSCLES IN PILATES PRACTITIONERS AND NON-PRACTITIONERS

Tese apresentada à Faculdade de Odontologia de Piracicaba da Universidade Estadual de Campinas, como parte dos requisitos exigidos para obtenção do título de Doutora em Biologia Buco-Dental, na área de Anatomia.

Thesis presented to the Piracicaba Dental School of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor in Oral Biology, in Anatomy area.

Orientador: Prof. Dr. Fausto Bérzin

Este exemplar corresponde à versão final da tese defendida pela aluna Ana Carolina Panhan e orientada pelo Prof. Dr. Fausto Bérzin.

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RESUMO

O método Pilates é um programa de exercícios físicos baseados na contrologia, que é definida como o controle consciente entre corpo, mente e espírito. Os exercícios do método são específicos para recrutar os músculos do core. Nesse sentido, foram realizadas avaliações eletromiográficas do músculo multífido (MU), músculo longuíssimo torácico (LO), músculo reto do abdome (RA) e músculo oblíquo interno (OI), durante exercícios de Pilates (solo e Wunda Chair) e durante testes de torque isométrico de extensão do tronco em mulheres de 18 a 30 anos que praticavam Pilates e em mulheres que não praticavam o método. Foram calculados os valores de eficiência neuromuscular (ENM) dos músculos extensores do tronco, bem como a porcentagem de atividade eletromiográfica dos músculos abdominais durante os exercícios de solo em três bases de suporte diferentes para o tronco e a porcentagem de co-contração entre músculos abdominais e dorsais (estabilizadores e mobilizadores) durante os exercícios na Wunda Chair. O teste t foi utilizado para comparar os resultados referentes à eletromiografia (EMG), ENM e pico de torque isométrico entre praticantes e não-praticantes de Pilates. A análise de variância de medida repetida (ANOVA) foi usada para verificar a diferença na atividade muscular entre os músculos RA e OI entre as três bases de suporte. O teste t pareado foi utilizado para verificar a diferença na porcentagem de co-contração entre estabilizadores e mobilizadores separadamente para cada exercício. Os dados foram expressos em média e desvio padrão (DP). A significância estatística foi estabelecida em $p < 0,05$ para todos os testes. As praticantes de Pilates apresentaram valores maiores de Pico de Torque e de ENM. Os músculos abdominais apresentaram maior atividade quando testados sobre a menor base de suporte para o tronco e a porcentagem de co-contração foi maior para os músculos estabilizadores em relação aos mobilizadores. Os exercícios do método podem ser eficientes para melhorar a ENM e o pico de torque, bem como recrutar os músculos abdominais, principalmente os músculos estabilizadores da coluna vertebral.

Palavras-Chave: Técnicas de exercício e de movimento, eletromiografia, cinesiologia aplicada, biomecânica.

ABSTRACT

The Pilates Method is a exercise program based in contrology, that is defined as conscious control between body, mind and spirit. The method exercises are specific to recruiting the core muscles. In this sense, electromyographic evaluations of the multifidus muscle (MU), longissimus muscle (LO), rectus abdominis muscle (RA) and internal oblique muscle (IO) were performed during Pilates exercises (mat and Wunda Chair) and during torque isometric extension test in women aged 18 to 30 who practiced Pilates and women who did not practice the method. Neuromuscular efficiency (NME) values of trunk extensor muscles were calculated, as well as the percentage of electromyographic activity of the abdominal muscles during ground exercises on three different support bases for the trunk and the percentage of abdominal muscle co-contraction and dorsal muscles (stabilizers and mobilizers) during exercises on the Wunda Chair. The t-test was used to compare the results regarding electromyography (EMG), ENM and isometric torque peak between Pilates practitioners and non-practitioners. Repeated-measure analysis of variance (ANOVA) was used to verify the difference in muscle activity between the RA and IO muscles between the three support bases. The paired t-test was used to verify the difference in the percentage of co-contraction between stabilizers and mobilizers separately for each exercise. Data were expressed as mean and standard deviation (SD). Statistical significance was set at $p < 0.05$ for all tests. Pilates practitioners had higher Torque Peak and NME values. Abdominal muscles showed higher activity when tested on the lowest support base for the trunk and the percentage of co-contraction was higher for stabilizer muscles than mobilizers. The method exercises can be effective in improving NME and peak torque, as well as recruiting the abdominal muscles, especially the spinal stabilizer muscles.

Keywords: exercise movement techniques, electromyography, kinesiology applied, biomechanics

SUMÁRIO

1. INTRODUÇÃO

Os movimentos que realizamos em nosso cotidiano, ou mesmo as ações mais complexas realizadas por atletas em seus respectivos esportes são executados com maior qualidade se a coluna vertebral manter-se estabilizada pelos músculos do core (Frank et al 2013; Yu et al, 2012), que é uma unidade integrada composta de 29 pares de músculos que suportam o complexo quadril-pélvico- lombar (Akuthota et al., 2008). Para garantir a estabilização, esses músculos precisam ser treinados adequadamente (Kolyniak et al, 2004), e uma das alternativas para o treinamento do core são os exercícios do método Pilates, sejam eles realizados no solo, com acessórios e também com o auxílio de aparelhos (Klizieni et al, 2017)

O método Pilates promove vários benefícios como alinhamento postural, condicionamento físico, flexibilidade, força, equilíbrio e consciência corporal (Latey, 2001). Os exercícios desafiam a estabilidade do tronco, ativam os músculos estabilizadores — múltífido (MU) e oblíquo interno (OI) e os mobilizadores do tronco — reto do abdome (RA) e longuíssimo do tórax (LO) (Bergmark, 1989; Gibbons e Comerford 2001; Cardozo e Gonçalves, 2006), que fazem parte dos músculos do core.

Segundo Pajanbi (1992; 2003) existem três subsistemas que se interagem para gerar e manter a estabilidade dos segmentos da coluna, sendo eles compostos por músculos esqueléticos, o que se pode chamar de subsistema ativo, pois cercam a coluna vertebral. As vértebras e suas estruturas articulares compõe o subsistema passivo, e por fim o subsistema neural controla mecanismos aferentes e eferentes do sistema nervoso.
A junção dos subsistemas, em condições normais, proporcionam o recrutamento adequado dos músculos e consequentemente promovem a estabilidade dinâmica da coluna vertebral.

Estudos mostram que o treinamento com o método Pilates pode aumentar o torque articular (Kolyniak et al, 2004) e a eficiência neuromuscular (ENM) (Marés et al, 2012), que é a relação entre um estímulo neural e a capacidade de geração de força de um músculo. É calculada da seguinte forma: valor do pico de torque dividido pelo valor do sinal eletromiográfico durante a contração isométrica máxima. Quanto maior o valor de torque e menor o valor da eletromiografia (EMG), melhor será a ENM (Tesch et al, 1990).

A EMG vem se tornando uma técnica importante para estudar a função do sistema neuromuscular do tronco durante a realização de exercícios do método Pilates

(Silva et al 2009; Silva et al 2015; Loss et al, 2011), e também durante testes laboratoriais, por isso, está sendo amplamente utilizada por profissionais de diversas áreas da saúde (Klizieni et al, 2017; Kolyniak et al, 2004; Sekendiz et al, 2007).

O método Pilates é amplamente utilizado no condicionamento físico e reabilitação, mas ainda existe a necessidade de verificar se o mesmo é eficiente para aumentar a ativação dos músculos do core e a ENM. Nesse sentido, verificar quais são os músculos recrutados durante a realização dos execícios do Pilates e o comportamento desses músculos em testes biomecânicos são de suma importância, para que haja uma orientação precisa dos profissionais habilitados para com os seus pacientes e/ou alunos.

2. ARTIGO 1: NEUROMUSCULAR EFFICIENCY OF THE MULTIFIDUS MUSCLE IN PILATES PRACTITIONERS AND NON-PRACTITIONERS

Complementary Therapies in Medicine

Short Report

NEUROMUSCULAR EFFICIENCY OF THE MULTIFIDUS MUSCLE IN PILATES PRACTITIONERS AND NON-PRACTITIONERS

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Abstract

Background: Pilates exercises help stabilize the vertebral segments by recruiting the abdominal and spinal muscles. Pilates training may increase joint stability and improve neuromuscular efficiency (NME).

Objective: This study aimed to evaluate NME of the multifidus (MU) muscle through electromyography (EMG) analysis and torque test, applied to practitioners and non-practitioners of Pilates.

Methods: Participants included thirty women: Pilates practitioners (n=15) and non-practitioners (n=15). They were tested for trunk extension. Their right and left MU muscles were submitted to EMG to estimate NME. Results concerning torque, EMG, and NME from all participants were compared.

Results: Statistical analysis concerning isometric torque peak ($p = 0.0275$) and NME ($p = 0.0062$) showed significant difference (Student t test; $p < 0.05$) between practitioners and control. No significant difference ($p = 0.3387$) in EMG was observed.

Conclusion: Our results suggest Pilates exercises is effective in training spinal muscles to improve NME in women.

Keywords: EMG, torque, trunk, core, biomechanics.

Introduction

The multifidus (MU) muscle is mono-articular and bilaterally inserted in the vertebrae. Despite its limitation towards torque, it stabilizes the spine, keeping it in a neutral position and producing eccentric contractions that aid in controlling the spinal movements.[1,2]

Pilates exercises, developed by Joseph H. Pilates, increase torque[3] and decrease lumbar pain in adult women.[4] Such exercises are known to stabilize the vertebral segments by recruiting the deep abdominal and spinal muscles[5,6] and intensify the activity of the stabilizing and mobilizing trunk muscles.[1,2]

Pilates training may increase joint stability[7] and improve neuromuscular efficiency (NME). Biomechanically, NME is calculated by the relationship between neural stimulus and the force-generating capacity of a muscle and is interpreted as an individual's ability to generate momentum in relation to their muscle activity level measured by electromyography (EMG).[8]

NME involves neuromuscular adaptation, varying according to gender, pathology, and training.[9,10] It is calculated as follows: the torque peak value divided by the EMG signal value during maximal isometric contraction.[9-15] The higher the torque value and the lower the EMG value, the better the NME.[9]

The aim of this study was to evaluate NME of the multifidus muscle through EMG analysis and torque test, applied to practitioners and non-practitioners (control) of Pilates.

Methods

Participants

This study was approved by the Ethics Committee of Piracicaba Dental School, University of Campinas (UNICAMP), Brazil (protocol: 5418/2017). All procedures were conducted at a laboratory of biomechanics (LABIOMEC), department of physical education, São Paulo State University (UNESP), Rio Claro, São Paulo, Brazil. Participants included thirty women: fifteen Pilates practitioners (years of practice: 4.3±1.4; age: 27.6±3.7 years; body mass: 58.7±2.5 kg; height: 1.66±0.03 cm); and fifteen non-practitioners (age: 21.4±1.6 years; body mass: 62.5±3.85 kg; height: 1.65±0.08 cm).

As inclusion criteria, the Pilates practitioners had to have at least six months of experience — minimally twice a week[14] — with no history of orthopedic and neurologic disorders, cardiovascular diseases, and surgery of the spine or abdomen.[16] Those practicing physical activities other than Pilates exercises were excluded. The non-practitioners (control) had to be sedentary or free of regular physical activities for at least one year prior to the study.

Data collection and procedures

The electrode placement site was shaved and cleansed with 70% alcohol.[17] To measure the EMG activity of the MU, electrodes were placed bilaterally, 3 cm away from the midpoint of the line ranging from L1 to L5 vertebrae (spinous process).[18-20] After placement of the electrodes, to avoid spinal damages, all participants did a warm-up by undergoing the submaximal isometric trunk extension test.[7] EMG values were expressed as root mean square (RMS).

The isometric torque peak exerted during the extension test was measured with an isokinetic dynamometer (System 4 Pro, Biodex®, Shirley, New York, USA). A chair was attached to the dynamometer to test the spinal movements. The test involved three 5-sec repetitions — with an interval of 30 seconds. The highest torque value was used to calculate NME. The angle of the waist and thigh was set at 90°.[4]

Before the test, starting 10 min after the warm-up,[21] the participants were instructed not to move their head and to keep their arms crossed over the chest. During the test, the participants had to statically extend their trunk to the maximum.

A direct transmission system (Noraxon®, Scottsdale, AZ, USA), with the myoMUSCLE software (TELEmyo DTS, 16 channels, 1500 Hz), was used to capture the EMG biological signals using 1-cm-in-diameter Ag/AgCl electrodes (Miotec®, Porto Alegre, Rio Grande do Sul, Brazil) set 2 cm apart. The software was set at a total gain of 2,000 times (20 times for the sensor and 100 times for the equipment) with an analog-digital converter resolution of 16 bits.

EMG signals were filtered (4^{th}-order Butterworth) at frequencies ranging from 20 to 500 Hz and analyzed using the Matlab software (version 2009, Natick, MA, United States). To calculate the NME value for MU, the extension torque value was divided by the sum of the EMG values obtained from both sides.[9-15]

Statistical analysis

Data were submitted to the Matlab software (version 2009, Natick, MA, United States) for all statistical tests. Data normality was assessed by D'Agostino test. The t-test was used to compare EMG, NME, and isometric torque peak between practitioners and control. The Cohen test was used to verify the power size of the comparisons. Data were expressed as mean values and standard deviation (SD). The statistical significance level was set as $p<0.05$.

Results

Data concerning isometric torque peak, EMG expressed by maximum root mean square (RMS), and NME are shown in Table 1. Statistical analysis concerning the isometric torque peak (p = 0.0275) and NME (p = 0.0062) showed significant difference (Student t test; p <0.05) between practitioners and control. No significant difference (p = 0.3387) in RMS was observed between the groups.

Table 1. Isometric torque peak ($N.m^{-1}$), EMG activity expressed in root mean square (RMS) microvolts and Neuromuscular Efficiency (NME)

		Control	**Practitioners**
Isometric Peak of Torque ($N.m^{-1}$)	mean±SD	185.7±16.4	240.1±28.8
	P	0.0275*	
	D	2.3	
EMG RMS (microvolts)	mean±SD	145.4±45.1	165.1±55.9
	P	0.3387	
	D	0.35	
Neuromuscular Efficiency (NME)	mean±SD	0.67±0.27	1.83±0.89
	P	0.0062*	
	D	1.76	

Asterisk (*) represents p < 0.05

Conclusion

Although no significant difference in EMG was observed, our isometric analysis showed significantly higher values concerning isometric torque peak and NME for Pilates practitioners, suggesting Pilates exercise is effective in training spinal muscles to improve NME in women. Further studies involving both genders, anthropometric factors, and different muscles are needed to confirm our findings.

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3. ARTIGO 2: ELECTROMYOGRAPHIC EVALUATION OF TRUNK CORE MUSCLES DURING PILATES EXERCISE ON DIFFERENT SUPPORTING BASES

Journal of Bodywork and Moviment Therapies

Electromyographic evaluation of trunk *core* muscles during Pilates exercise on different supporting bases.

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Abstract

Objective: To evaluate the electromyographic (EMG) activity of the rectus abdominis (RA) and internal oblique (IO) muscles during Pilates exercise on different trunk supporting bases.

Methods: Sixteen women (Pilates practitioners) participated in the study. EMG of the RA and OI muscles was evaluated during the double leg stretch (DLS) exercise on three different supporting bases — mat, long box, and short box. Trunk stability varies according to the size and type of the base. To normalize the data, the RMS value (EMG) obtained during the DLS exercise was divided by the RMS value from the torque test — the maximal voluntary isometric contraction (MVIC) — and multiplied 100 times (%MVIC). One-way repeated-measured analysis of variance (ANOVA) and Bonferroni tests were used to compare data concerning the supporting bases and Student t-test regarding the muscles ($p < 0.05$).

Results: The comparison among the bases involving each muscle — RA or IO ($p<0.05$) — showed significant difference (%MVIC) between the mat and the short box. No significant difference was observed between the muscles, concerning the exercise on the mat ($p = 0.9266$), on the long box ($p = 0.5113$) and on the short box ($p = 0.2972$).

Conclusion: The short box increased the activity of the rectus abdominis and internal oblique muscles during exercise. The DLS exercise was able to challenge the stability of the trunk and thus recruit its stabilizer and mobilizer muscles at the same intensity.

Keywords: Pilates method, EMG, core muscles, trunk.

Introduction

The Pilates method is a physical exercise program based on “contrology,” defined by Joseph Pilates as the conscious control of all body movements and complete coordination of body, mind, and spirit. It provides practitioners with a physical and mental well-being (Pilates and Miller, 1998). This program involves exercises that improve stretching, strength and proprioception, all of which provide better posture, muscle control, and breathing (Muscolino and Cipriani, 2004; Panelli and De Marco, 2009). It is widely used to prevent and treat muscle and joint lesions (Blum, 2002; Natour et al, 2015).

Pilates exercise is basically aimed at the core muscles — rectus abdominis, internal oblique, and transverse abdominal muscles — which are partially responsible for spinal stability (Silva et al, 2009). The core is an integrated unit composed of 29 pairs of muscles that support the hip-pelvic-lumbar complex (Akuthota et al, 2008). It is directly related to the Pilates method, whose exercises aim to improve the strength and dynamic control of such muscles.

The Pilates method includes two categories — mat and apparatus, both of which recruit the abdominal muscles (frontal core muscles). Exercises on the mat use body weight and gravitational force as a form of resistance (Muscolino and Cipriani, 2004). Accessories, such as the magic circle, neck stretcher, foot corrector, toe exerciser, push up device, airplane board, sand bag and weights, are included when appropriate (Panelli and De Marco 2009).

Several studies have evaluated the electromyographic (EMG) activity of the core muscles during Pilates exercises, both on the mat and the apparatus. Such exercises were reported as effective in strengthening the core muscles (Queiroz et al., 2010; Marques et al., 2013; Dias et al., 2014; Silva et al, 2015).

The rectus abdominis muscle — the major flexor of the trunk (Norris, 1993) — plays an important role in spinal stability (Norwood et al., 2007). The internal oblique muscles — lateral flexors and rotators of the trunk — also contribute to spinal stability (Norwood et al., 2007), and, thus, are recruited during Pilates exercise (Rossi et al, 2014).

Some factors may increase the EMG activity of the paravertebral and flexor muscles during Pilates abdominal exercises. Among the factors is the use of unstable bases, such as a roller or a ball (Kim et al, 2011; Marshall and Murphy, 2005; Andrade et al., 2015).

While elaborating specific protocols aimed at training and/or rehabilitation, Pilates instructors should know what abdominal muscles are recruited and how active they are during Pilates exercise on different supporting bases. This might help them establish adequate exercise for all levels of training. Therefore, the present study aimed to analyze the effect of different trunk supporting bases on the EMG activity of the rectus abdominis (RA) and internal oblique (IO) muscles during the double leg stretch (DLS) exercise. Our hypothesis is that the smaller the trunk supporting base, the lower the trunk stability, resulting in a more intense activity of the RA and IO muscles during exercise.

Methods

Participants

Participants included sixteen right-handed women with a height and body weight of 1.64 ± 0.04 m and 58.7 ± 7.4 kg, respectively, and a mean age of 27.6 ± 3.7 years. They were randomly selected in two 'classic' Pilates studios, where they had been practicing for 4.1 ± 1.3 years, considering the following inclusion criteria: (a) women practicing Pilates for at least six months and having no musculoskeletal damage, (b) no pregnancy, and (c) no visually-identified asymmetries in the spinal trunk and lower limbs (Silva et al., 2015). This study was approved by the ethics and research committee of Piracicaba Dental School, University of Campinas (Unicamp): protocol 5418/2017.

Data recording

A direct transmission system (TELEmyo DTS, 16 channels, 1500 Hz), along with the software myoMUSCLE (Noraxon®, Scottsdale, AZ, USA), was used to capture the electromyographic biological signals. The software was set at a total gain of 2,000 times (20 times for the sensor and 100 times for the equipment), with an analogue-digital converter resolution of 16 bits and an analogue bandpass filter (20–500 Hz). Ag/AgCl surface electrodes (Miotec®,Porto Alegre, Rio Grande do Sul, Brazil) were 10 mm in diameter. The root mean square (RMS) values obtained from the DLS exercise were normalized by the RMS values obtained during the maximal voluntary isometric contraction (MVIC) test measured with the isokinetic dynamometer (System 4 Pro, Biodex® , Shirley, New York, USA) during each exercise (Escamilla et al., 2010).

All experimental procedures were carried out at the Laboratory of Biomechanics (LABIOMEC), UNESP, Rio Claro, São Paulo, Brazil. For data collection, volunteers first did an active warm-up of their trunk muscles for approximately 2 minutes — 40 sec for alternate trunk rotation, 40 sec for alternate trunk flexion, and 20 sec for static stretching on each side — in a standing position.

After the warm-up, the electrode placement site was shaved and cleansed with 70% alcohol to reduce impedance. The electrodes were placed on the dominant side of each participant on both muscles: IO — 2 cm medially and inferiorly to the anterior superior iliac crest; and RA — 3 cm away from the midpoint of the midline — navel to xiphoid process (Marques et al., 2013).

All participants were tested for the MVIC of the trunk flexion in a sitting position (see Figure 1). The shoulders, torso, and thighs of the participants were secured by straps, and the angle between the waist and thigh was fixed at 90° (Klizieni et al, 2016). They did a 5-sec warm-up prior to the test, which involved three 5-sec maximal flexion contractions, with 30-sec intervals between contractions (Gruther et al., 2009). They were instructed to carry out the contractions as fast and as strong as they could and were verbally stimulated during the test. The highest torque value of such contractions was established as the trunk flexion MVIC.

Fifteen minutes after the MVIC test, all participants did DLS exercises on three different supporting bases — mat (120x100x5 cm), long box (90x45x55 cm), and short box (40x20x35 cm) — with a 10-min interval (Silva et al, 2015). They were instructed to do eight repetitions of exercise for each base under the 50 bpm metronome rhythm, in accordance with standard protocols of the Pilates method (Pilates and Miller, 1998). The order of each exercise supporting base was established by drawing.

The DLS exercise, for all supporting bases (see Figure 2), started in a supine position (neck flexion and trunk flexion), with their hip and knees flexed toward the chest and their hands below the patella, followed by extended upper and lower limbs, with their head, shoulders, arms, and legs off the supporting base. The exercise was done according to a protocol described by Silva et al. (2015) — inspiration was done during knee flexion and expiration during extended legs and arms.

EMG signals were analyzed using specific routines developed in Matlab software (version 2009, Natick, MA, United States) as they were filtered (4^{th}-order Butterworth) at 20–500 Hz frequencies and processed in the time domain.

Figure 1. Trunk flexion test: MVIC values.

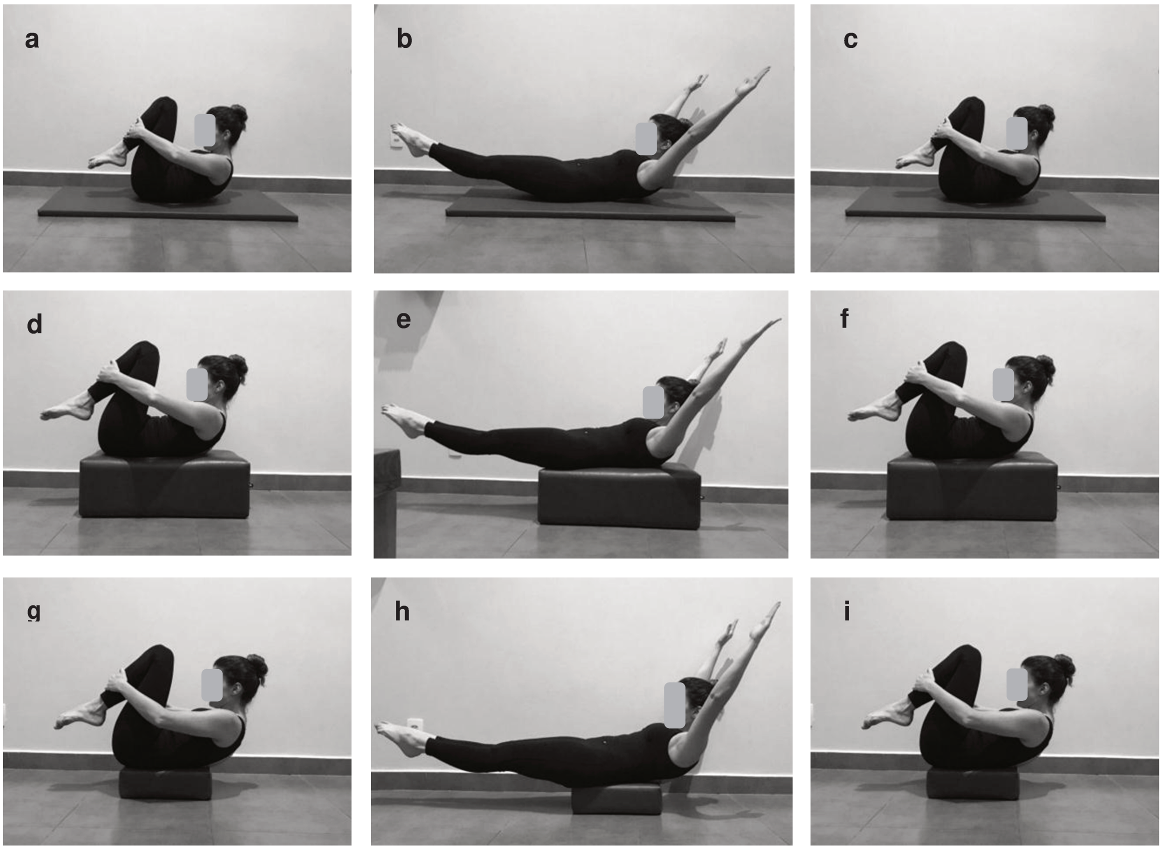

Figure 2. Individuals' positions during exercise on the supporting bases: mat (a,b,c); long box (d,e,f); and short box (g,h,i).

Data analysis

The BioEstat 5.3 software (version 2007, Belem, PA, Brazil) was used to analyze the data concerning all statistical tests. Data normality was assessed by the D'Agostino test. One-way repeated-measured analysis of variance (ANOVA) was used to verify difference in muscle (RA and IO) activity among three supporting bases. The post-hoc Bonferroni test was applied when necessary. The Student t test was used to verify difference in muscle activity concerning each supporting base separately. Statistical significance was set at $p < 0.05$ for all tests. Data were expressed as mean and standard deviation (SD).

Results

Figure 3a (i and ii) shows the EMG values — expressed as percentage of maximal voluntary isometric contraction (%MVIC) — of the RA and IO muscles, which were assessed and compared among the three bases. The highest values concerning both muscles were observed for the exercise on the short box (84% and 92%, respectively), followed by the long box (66% and 71%) and the mat (55% and 57%). ANOVA and Bonferroni tests showed statistically different %MVIC values between the mat and short box, regarding RA ($p < 0.05$) and IO ($p < 0.05$).

Figure 3b (i, ii and iii) shows a comparison between muscles for each supporting base. Statistical analysis (Student t test; $p < 0.05$) showed no significant difference between the muscles, concerning exercise on the mat ($p = 0.9266$), on the long box ($p = 0.5113$) and on the short box ($p = 0.2972$).

Based on our results, all supporting bases showed intense activity of the muscles assessed. High intensity levels were detected for the mat and very high for the long and short boxes, with the latter showing the highest levels (Digiovine et al, 1992; Escamila et al, 2010).

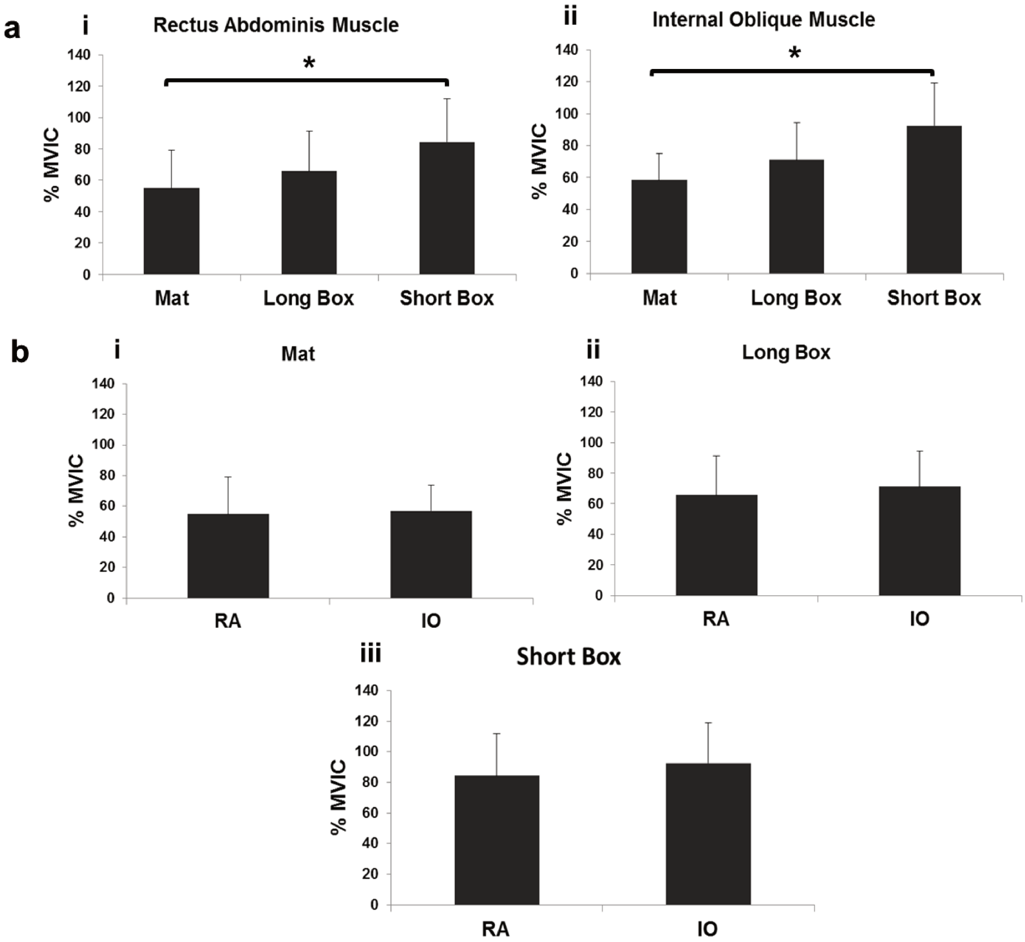

Figure 3a. MVIC values for (i) Rectus Abdominis and (ii) Internal Oblique considering the three supporting bases. Asterisk (*) represents $p < 0.05$. **Figure 3b.** Differences in muscle activity among supporting bases: (i) mat; (ii) long box; and (iii) short box.

Discussion

The Pilates method has been recommended for therapeutic purposes or physical fitness in healthy individuals, aiming at some particular muscles. However, no studies have been found to investigate EMG of the RA and IO trunk muscles during Pilates exercise on supporting bases of different sizes. Our hypothesis was that the smaller the trunk supporting base, the lower the trunk stability, resulting in a more intense activity of the RA and IO muscles during exercise.

Since the RA and IO muscles are responsible for trunk stability, they are expected to be more recruited on a stable base (Behm and Colado, 2012). Although not targeted in the present study due to complexities involving EMG signal interference and difficulties in accessing it, the transversus abdominis muscle — which maintains the intra-abdominal pressure — is fundamental for trunk stability. The thoracolumbar fascia also has an important role; it is attached to the internal oblique and transverse abdominis muscles and thus provide three-dimensional support to the lumbar spine and aid in core muscle stability (Young et al, 1996).

Previous studies (Digiovine et al, 1992; Escamila et al, 2010) have categorized the muscle activity EMG values (%MVIC) into four intensity levels: low (<21%), moderate (21–40%), high (41–60%), and very high (>60%). Levels of %MVIC greater than 45% are likely to induce muscle strengthening (Ekstrom et al., 2007). In the present study, %MVIC values were greater than 45% for RA and IO during exercise on the three different supporting bases, suggesting that the targeted exercise can be used to strengthen the core abdominal muscles.

Trunk stability depends mostly on the intensity and the individual's positioning adopted for each exercise (Loss et al., 2010). In the present study, the exercise on the short box showed the highest MVIC values (Fig. 3a). This might be due to the smaller base resulting in a lower stability of the trunk, a condition in which the abdominal muscles, especially the RA and IO, are recruited to give more stability to the trunk.

Comparison between the two muscles considering each of the three supporting bases separately showed no statistical differences in muscle activity (Fig. 3b). The exercise applied was able to challenge the stability of the trunk and thus recruit its stabilizer (IO) and mobilizer muscles (RA) at the same intensity (Bergmark, 1989; Gibbons and Comerford, 2001; Cardozo and Gonçalves, 2006).

The abdominal muscles are responsible for trunk stability as they reduce the load on the spine during body movements; such muscles, if weak, might generate biomechanical disorders and pain in the back (Axler and McGill, 1997). While choosing the exercise to strengthen the abdominal muscles, the Pilates instructor should be aware that each abdominal muscle plays a particular role in stabilizing and mobilizing the spine (Comerford et al. 2011). Strengthening the core muscles is fundamental for stabilizing the spine and preserving its structures and the trunk functions (Rossi et al., 2014).

Our results showed that the muscle activity increased as the size of the base decreased; our findings might help Pilates instructors decide over the size of the trunk supporting bases, according to their students' levels — basic, intermediate or advanced. The trunk supporting base size could be reduced as the level advances.

Limitations

Although the sample size is deemed adequate for the present investigation, a larger number of Pilates exercises would result in a more substantial impact on our findings and allow the authors to investigate other muscles. Also, a comparison between practitioners and non-practitioners would help eliminate bias. Muscle activation might respond differently in non-practitioners.

Conclusion

The short box increased the activity of the rectus abdominis (RA) and internal oblique (IO) muscles during the Pilates exercise assessed. EMG values (%MVIC) concerning both muscles were statistically different among the bases. The more unstable the supporting bases of the trunk, the more its mobilizer (RA) and stabilizer (IO) muscles were recruited.

Practical Application

- The results of this study provide Pilates instructors with information on the EMG characterization of double leg stretch exercise on trunk supporting bases of different sizes.
- EMG analysis can be used to establish Pilates exercise levels.
- Further studies involving individuals with different clinical conditions and other muscle groups and types of exercise are needed to confirm our findings and develop protocols aimed at Pilates exercises for specific purposes.

Conflict of interest

None

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4. ARTIGO 3: CO-CONTRACTION OF THE CORE MUSCLES DURING PILATES EXERCISE ON THE WUNDA CHAIR

Journal of Back and Musculoskeletal Rehabilitation

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Abstract

BACKGROUND: The co-contraction of the core muscles has been reported as the key mechanism towards spinal stability. Classic Pilates exercises aimed at these muscles are known to improve the stability and strength of the trunk without damaging the deep structures of the spine.

OBJECTIVE: To evaluate the co-contraction of the mobilizing (rectus abdominis; longissimus) and stabilizing (multifidus; internal oblique) trunk muscles during Pilates exercises — going up front, mountain climber, and swan.

METHODS: Sixteen women — Pilates practitioners — participated in the study. The stabilizing and mobilizing muscles of the trunk (right side) were submitted to electromyography to calculate the percentage of co-contraction during the exercises. One-way repeated-measures analysis of variance (ANOVA) was used to verify the difference in %COCON between stabilizers and mobilizers among the three exercises. The post-hoc Bonferroni test ($P<0.01$) was applied when necessary. The paired t-test ($P<0.01$) was used to verify the difference in %COCON between stabilizers and mobilizers separately for each exercise.

RESULTS: The co-contraction values of the stabilizers were higher than those of the mobilizers for all exercises. The going up front (stabilizers) and the swan (mobilizers) exercises showed the highest %COCON values.

CONCLUSIONS: The Pilates method is effective in either rehabilitating pathologies or training the trunk muscles in healthy individuals and athletes.

Keywords: Pilates method, EMG, core muscles, trunk

Introduction

The core muscles are known to stabilize the spine and, if stimulated adequately, allow better quality of the daily body movements, including those made by athletes in their respective sports [1,2]. To ensure spinal stability, these muscles need to be trained properly [3]. One of the alternatives for core muscle training is the Pilates exercise, whether done on the mat or on apparatuses [4,5].

The Pilates method provides practitioners with several benefits, such as postural alignment, fitness, flexibility, strength, balance and body awareness [6]. It consists of six fundamental principles: concentration; control; fluidity; precision; breathing; and centralization [7]. Centralization is based on an isometric contraction of the abdomen's internal oblique and transverse muscles, resulting in an increased antagonistic co-contraction of the low back muscles [8].

Pilates exercises challenge the stability of the trunk and intensify the activity of its stabilizing (multifidus; internal oblique) and mobilizing (rectus abdominis; longissimus) muscles. Such muscles are also referred to as stabilizers and mobilizers [9,10].

The stabilizers are mono-articular, deeper, and directly inserted in the vertebrae. Despite their limitation towards torque, they control the segmental movement of the spine, keeping it in a neutral position and producing eccentric contractions that aid in stabilizing and controlling the spinal movements. As for the mobilizers, with their great resistance to external forces, they have optimal torque ability and can also control the spinal movements [9,11].

The co-contraction of the trunk core muscles increases the stability of the vertebral column and protects its structures during functional activities and physical exercises [14]. Classic Pilates exercises aimed at these muscles are known to improve the conditioning and strength of the trunk muscles without damaging the deep structures of the spine [14].

Using mathematical software to calculate the forces exerted by all muscles that surround a joint is ideal for quantifying muscle co-contraction. However, this approach is time-consuming and its outcomes often show limitations and assumptions, leading researchers and clinicians to rely on electromyography (EMG) to measure muscle co-contraction [15]. EMG has been used to analyze the function of the neuromuscular trunk system [16-19] and to verify the co-contraction of the antagonist muscles [20] during Pilates exercises.

The Wunda Chair, an apparatus engineered by Joseph Pilates, is commonly used in classical Pilates. It consists of two removable springs, a pedal, and a seat. Exercises can be carried out with the feet or hands resting on its pedal or seat, in three decubitus positions —

dorsal, lateral, or ventral [7].

No studies have been found to evaluate the co-contraction of the mobilizing and stabilizing muscles of the trunk during Pilates exercises using the Wunda Chair. Therefore, the aim of this study was to evaluate and compare the co-contraction of the mobilizing and stabilizing trunk muscles during Pilates exercises — going up front, mountain climber, and swan — conducted in the Wunda Chair.

The first hypothesis of our study was that, during these exercises, the co-contraction of the stabilizers (multifidus; internal oblique) might be greater than that of the mobilizers. The second hypothesis was that the co-contraction values would vary among the three exercises since they involve different trunk positions.

Methods

Participants

Fifteen young female Pilates practitioners (Table 1) participated in this study. Exclusion criteria were orthopedic disorders, neurological problems, cardiovascular disease, and surgery of the spine or abdomen [18]. The inclusion criteria were: 18–35-year-old women who were right-limb dominant and had been practicing the method for at least six months.

Table 1. Mean values of body anthropometrics, age, and time of practice

	Mean (±SD)
Mass (Kg)	58.7 (7.4)
Height (m)	1.64 (.04)
Body Mass Index (Kg.m2)	21.8 (2.4)
Age (years)	27.6 (3.7)
Time of Practice (years)	4.1 (1.3)

This study was approved by the Ethics Committee of Piracicaba Dental School, University of Campinas (UNICAMP), Brazil (protocol: 5418/2017). All experimental procedures were conducted at a laboratory of biomechanics (LABIOMEC), Department of Physical Education, São Paulo State University (UNESP), Rio Claro, São Paulo, Brazil.

Data Collection

Individuals' age, time of practice (years), weight, height, and body mass index were recorded at one session right before Pilates exercise. Their right side stabilizing — internal oblique (IO) and multifidus (MU) — and mobilizing — rectus abdominis (RA) and longissimus (LO) — trunk muscles were then submitted to EMG during the exercises. All exercises were supervised by a Pilates instructor with a degree in physical education.

Pilates Exercises and Equipment

Each individual did three Pilates exercises — going up front, mountain climb, and swan — on the Wunda Chair, containing one (Fig. 1) and two springs (Fig. 2), with a 10-minute interval [16]. Each exercise involved eight repetitions under a 50-bpm metronome rhythm, considering Pilates method's principles for practitioners and following the Pilates Method Alliance, PMI [7,21].

The going up front exercise (Fig. 3) started with the individuals in a sagittal position in relation to the equipment, resting the right foot on the pedal and the left on the seat, or top, of the Wunda Chair (two springs). As the exercise started, the individuals raised their arms and held them up to completion of the session. Repetitions involved the individuals standing up on their left foot on top of the chair until their left knee straightened all the way. Keeping their right foot on the pedal, they then lowered themselves back down to the starting position.

The swan (Fig. 4) started with the individuals in the ventral decubitus position with their iliac crests resting on top of the chair (one spring). With their spine extended and legs stretching out together parallel to the floor, they placed their hands on the pedal (held down to the base of the chair by an instructor), aligning them under their shoulders and straightening their arms. They inspired as they extended their back allowing the pedal to rise and expired as they lowered to the initial position

For the mountain climb (Fig. 5), individuals were instructed to keep their left foot on top of the chair (two springs), spine in flexion (C-curve), left thigh parallel to the floor, and arms stretching out at the level of their left knee. The leg on the pedal was free to pump up and down.

Figure 1. Wunda chair with one spring.

Figure 2. Wunda chair with two springs.

Figure 3 . Going up front exercise.

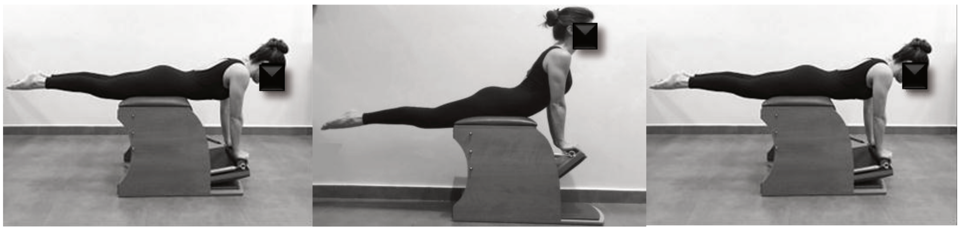

Figure 4 . Swan exercise.

Figure 5 . Mountain climb exercise.

Electromyography

A direct transmission system (TELEmyo DTS, 16 channels, 1500 Hz) with the software myoMUSCLE (Noraxon®, Scottsdale, AZ, USA) was used to capture the EMG biological signals using 10-mm-in-diameter Ag/AgCl surface electrodes (Miotec®, Porto Alegre, Rio Grande do Sul, Brazil) set 20 mm apart. The software was set at a total gain of 2,000 times (20 times for the sensor and 100 times for the equipment) with an analog-digital converter resolution of 16 bits.

For data collection, participants did an active warm-up of their trunk muscles from a standing position for approximately 2 minutes — 40 sec for alternate trunk rotation, 40 sec for alternate trunk flexion, and 20 sec for static stretch on each side. After the warm-up, the electrode placement site was shaved and cleansed with 70% alcohol to reduce impedance [22].

The electrodes were placed on the muscles (dominant side) assessed: IO — 2 cm medially and inferiorly to the anterosuperior iliac spine; RA — 3 cm away from the line (midpoint) ranging from the navel to the xiphoid process; LO — 2 cm away from the spinous process of the lumbar (L1) vertebra; and MU — 3 cm away from the line (midpoint) ranging from the spinous process of L1 to that of L5 vertebra [8,23,24,25].

EMG signals were filtered (4^{th}-order Butterworth) at 20–500 Hz frequencies and analyzed using the Matlab software (version 2009, Natick, MA, United States). The area under the signal amplitude curve obtained from the linear envelope concerning the four muscles assessed (RA, IO, LO, and MU) was used to calculate the percentage of the co-contraction (% COCON) of the mobilizing (RA and LO) and stabilizing (IO and MU) muscles considering an equation described by Winter, 2005. In the equation (Fig. 6), area A comprehends muscles RA or IO while area B involves muscles LO or MU [26]. A&B represents a common area of activity of the muscles involved. In accord with reports by Hopkins et al, 1999 and Heise et al., 2005 [27,28], EMG was not normalized.

$$\%COCON = 2 \times \frac{\text{common area A\&B}}{\text{area A} + \text{area B}} \times 100\%$$

Figure 6. Equation described by Winter, 2005. Area A comprehends muscles RA or IO while area B involves muscles LO or MU. A&B represents a common area of activity of the muscles involved.

Statistical analysis

Data were submitted to BioEstat 5.3 software (version 2007, Belem, PA, Brazil) for all statistical tests. Data normality was assessed by D'Agostino test. One-way repeated-measures analysis of variance (ANOVA) was used to verify difference in %COCON between stabilizers and mobilizers among the three exercises assessed. The post-hoc Bonferroni test was applied when necessary. The paired t-test was used to verify difference in %COCON between stabilizers and mobilizers separately for each exercise. Data were expressed as mean and standard deviation (SD). Since five tests were considered, the statistical significance level was defined as $p < 0.01$, obtained from the division of $p < 0.05$ by the number of tests.

Results

Figure 7a and b shows %COCON to mobilizers and stabilizers. As for the mobilizers (RA and LO), the highest %COCON value was detected for the swan exercise (43%), followed by going up front (34%) and mountain climb (25%). Significant difference was observed between the swan and mountain climb exercises (p = 0.0045; ANOVA and Bonferroni tests; Fig. 7a).

As illustrated in Fig. 7b, the going up front exercise (78%), when compared to the mountain climb (66%) and swan (57%), showed the highest %COCON value for the stabilizers (IO and MU). Statistically significant difference was observed between the going up front and swan exercises (p = 0.0083; ANOVA and Bonferroni tests).

Figure 8a–c shows a difference in %COCON between stabilizers and mobilizers for the three exercises assessed. Statistical analysis (Student t test; p < 0.01) showed significant difference between stabilizers and mobilizers concerning each exercise: going up front (p > 0.0001); mountain climb (p > 0.0001); and swan (p = 0.0043).

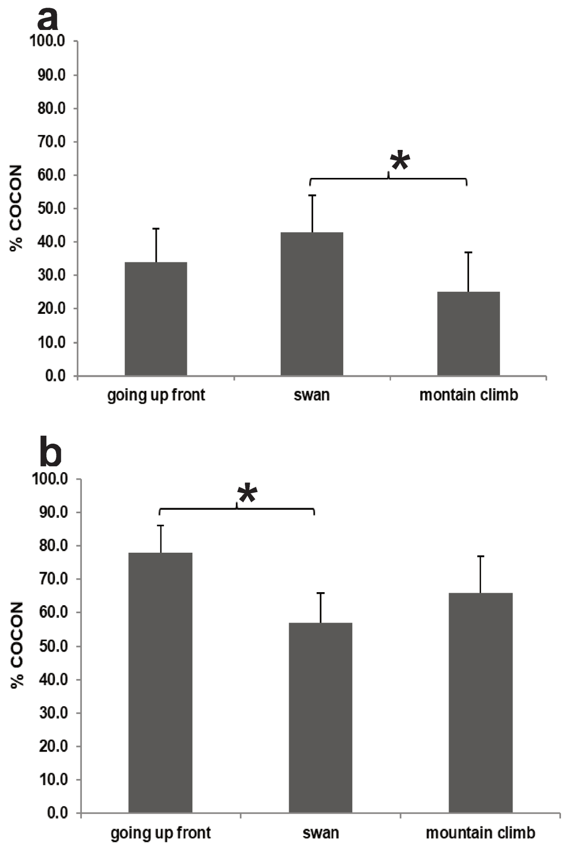

Figure 7. %COCON for (a) stabilizers and (b) mobilizers for all exercises.

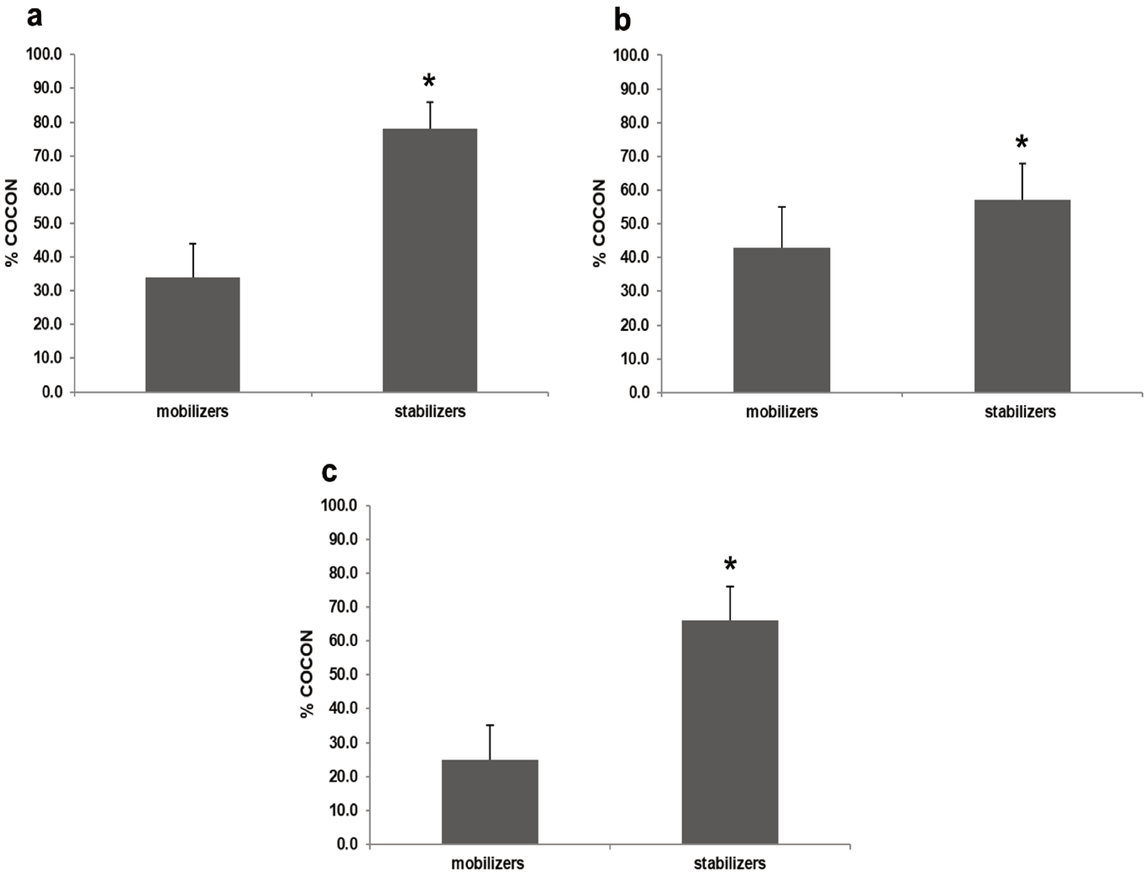

Figure 8. %COCON for stabilizers and mobilizers for each exercise: going up front (a), swan (b), and mountain climb (c).

Discussion

Based on Pilates' principle of centralization, an isometric contraction of the internal oblique and transverse muscles leads to an increased co-contraction of the abdominal and low back muscles. Hypotheses are that, during the exercise, (a) the %COCON values of the local muscles would be higher compared to that of the global muscles and that (b) the %COCON values would differ among the three exercises.

The first hypothesis was confirmed; %COCON of the stabilizers was greater than that of the mobilizers. The second hypothesis was partially confirmed, because no statistical difference in %COCON concerning the stabilizers was found between mountain climb and the other exercises; in relation to the mobilizers, no difference was observed between going up front and the other exercises.

The swan exercise, concerning the mobilizers, showed the highest %COCON value; this might be due to a co-activation of the abdominal (RA) and extensor (LO) muscles during the extension of the spine (pedal elevation). Proper abdominal muscle activation provides better support to the spine and, together with the extensor muscles, helps to create a long and uniformly distributed arch over the vertebrae and to control the torque generated by hip extension [11,29,30].

In relation to the stabilizers, the going up front exercise showed the highest %COCON value. This finding might be explained as follows: because the spine remains in a neutral position during this exercise, the stabilizers are more intensively recruited to maintain its vertebral stability and protect its structures, minimizing the disturbance of the vertebral segments created by upper and lower limb movements [9,31-33].

During the mountain climb exercise, the stabilizers (IO and MU) are recruited to maintain body posture and balance until completion of the exercise [6,34,35]. In the present study, because the spine was kept in flexion (C-curve) during this exercise, the %COCON of the mobilizers (RA and LO) was lower than those recorded for the other exercises applying no spine flexion. Such finding might be due to the RA muscle — the main flexor of the trunk [36] — being recruited more intensively than the LO muscle.

Rossi et al., (2014) [20] found results different from those observed in the present study, with the stabilizers showing significantly higher %COCON values than those found for mobilizers. To be included in the present study, participants had to be Pilates practitioners and familiar with the method; the participants in the previous study did not know the methodology and its principles. This might account for such difference in the values since supervised training makes a difference over the time.

Based on our results, the Pilates exercises assessed can be used to recruit the core muscles [4,5] by activating the individual's deep musculature [4]. Further studies, involving individuals with different clinical conditions and types of exercise, are needed to confirm our findings and to establish protocols aimed at Pilates exercises for specific purposes.

Conclusion

The co-contraction of the stabilizers was greater than that of the mobilizers for the three Pilates exercises assessed. The positioning of the trunk may increase or decrease co-contraction of these muscles; the more the physiological curvature (no flexion or extension) of the spine is maintained during the exercises, the more such muscles are recruited. The Pilates method is effective in either rehabilitating pathologies or training the trunk muscles in healthy individuals and athletes.

Limitations

The EMG evaluations were performed only unilaterally (right side of the body). Only three exercises were applied. Individuals included only Pilates practitioners.

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5. DISCUSSÃO

Os resultados abtidos a partir da avaliação isométrica (Artigo 1), mostraram valores significativamente maiores em relação ao pico de torque isométrico e ENM para praticantes de Pilates, sugerindo que o exercício de Pilates é eficaz no treinamento dos músculos da coluna para melhorar o NME em mulheres.

Estudos anteriores (Digiovine et al, 1992; Escamila et al, 2010) categorizaram os valores da atividade muscular em porcentagem da contração isométrica voluntária máxima (% CIVM) em quatro níveis de intensidade: baixo (<21%), moderado (21-40%), alto (41- 60%) e muito alto (> 60%). Níveis de % CIVM superiores a 45% provavelmente induzem o fortalecimento muscular (Ekstrom et al., 2007). No presente estudo (Artigo 2), os valores de % CIVM foram superiores a 45% para os músculos reto do abdome e oblíquo interno (RA e OI) durante o exercício nas três bases de suporte diferentes, sugerindo que o exercício direcionado pode ser usado para fortalecer os músculos do core.

A estabilidade do tronco depende principalmente da intensidade e do posicionamento do indivíduo adotado para cada exercício (Loss et al., 2010). O exercício na caixa curta apresentou os maiores valores de CIVM. Isso pode ser devido à menor base, resultando em uma menor estabilidade do tronco, uma condição na qual os músculos abdominais, especialmente a RA e a OI, são recrutados para dar mais estabilidade ao tronco.

A comparação entre os dois músculos, considerando cada uma das três bases de suporte separadamente, não mostrou diferenças estatísticas na atividade muscular. O exercício aplicado foi capaz de desafiar a estabilidade do tronco e, assim, recrutar seus músculos estabilizadores (OI) e mobilizadores (RA) na mesma intensidade (Bergmark, 1989; Gibbons e Comerford, 2001; Cardozo e Gonçalves, 2006).

Ao escolher o exercício para fortalecer os músculos abdominais, o instrutor de Pilates deve estar ciente de que cada músculo abdominal desempenha um papel particular na estabilização e mobilização da coluna vertebral (Comerford et al. 2011). O fortalecimento dos músculos do core é fundamental para estabilizar a coluna e preservar suas estruturas e as funções do tronco (Rossi et al., 2014).

Nossos resultados mostraram que a atividade muscular aumentava à medida que o tamanho da base diminuía; nossas descobertas podem ajudar os instrutores de Pilates a decidir sobre o tamanho das bases de apoio do tronco, de acordo com os níveis de seus alunos - básico, intermediário ou avançado. O tamanho da base de suporte do tronco pode ser reduzido à medida que o nível avança.

Em relação ao terceiro artigo: não foi encontrada diferença estatística na % de co-

contração entre o exercício Mountain Climb e os demais exercícios para os músculos estabilizadores (Multífidos e Oblíquo Interno – MU e OI) e também, não foi observada diferença entre o exercício Going Up Front e os demais para os músculos mobilizadores (Reto do Abdome e Longuíssimo do Torácico – RA e LO).

O exercício Swan apresentou o maior valor de % de co-contração entre os mobilizadores; isso pode ser devido a uma co-ativação dos músculos abdominais (RA) e extensores (LO) para manter a coluna vertebral (elevação do pedal). A ativação adequada do músculo abdominal fornece melhor suporte à coluna vertebral e, juntamente com os músculos extensores, ajuda a criar um arco longo e uniformemente distribuído sobre as vértebras e a controlar o torque gerado pela extensão do quadril (Hodges, 2003; McCook et al, 2009; Stokes et al, 2011).

O exercício Going Up Front apresentou o maior valor de % de co-contração entre os estabilizadores, esse achado pode ser explicado da seguinte forma: como a coluna permanece em uma posição neutra durante este exercício, os estabilizadores são recrutados mais intensamente para manter sua estabilidade vertebral e proteger suas estruturas, minimizando a perturbação dos segmentos vertebrais criados pelos movimentos dos membros superiores e inferiores (Bergmark 1989; Granata et al, 2005; Colado et al, 2011; Toprak et al, 2017).

Os músculos estabilizadores (IO e MU) são recrutados para manter a postura corporal e o equilíbrio até a conclusão do exercício Mountain Climb (Latey, 2001; Ferreira et al 2007; Johnson et al, 2007). Nesse exercício a coluna foi mantida em flexão (curva C) durante este exercício, e com isso os músculos mobilizadores apresentarm menor co-contração, tal achado pode ser devido ao músculo RA - o principal flexor do tronco - ser recrutado mais intensamente que o músculo LO (Norwood et al, 2007).

Rossi et al., (2014) encontraram resultados diferentes dos observados no presente estudo: Os músculos mobilizadores mostraram valores de % de co-contração significativamente mais altos do que os encontrados para estabilizadores. Os participantes do estudo de (Rossi et al, 2014) não conheciam a metodologia e seus princípios. Isso pode explicar essa diferença nos valores, pois o treinamento supervisionado faz a diferença sobre a atividade muscular ao longo do tempo.

Com base em nossos resultados, os exercícios de Pilates considerados podem ser utilizados para recrutar os músculos do core, ativando a musculatura profunda do indivíduo (Kolyniak et al, 2004; Klizieni et al, 2017). Mais estudos, envolvendo indivíduos com diferentes condições clínicas e tipos de exercício, são necessários para confirmar nossos achados e estabelecer protocolos direcionados aos exercícios de Pilates para fins específicos.

6. CONCLUSÃO

Embora não tenha sido observada diferença significativa no EMG, nossa análise isométrica mostrou valores significativamente maiores em relação ao pico de torque isométrico e ENM para praticantes de Pilates, sugerindo que o exercício de Pilates é eficaz no treinamento dos músculos da coluna para melhorar o NME em mulheres.

A caixa curta aumentou a atividade dos músculos reto do abdome e oblíquo interno durante o exercício de Pilates avaliado. Os valores de EMG (% CIVM) referentes aos dois músculos foram estatisticamente diferentes entre as bases. Quanto mais instáveis as bases de sustentação do tronco, mais seus músculos mobilizadores (reto do abdome) e estabilizadores (oblíquo interno) foram recrutados.

A co-contração dos estabilizadores foi maior que a dos mobilizadores para os três exercícios de Pilates avaliados. O posicionamento do tronco pode aumentar ou diminuir a contração desses músculos; quanto mais a curvatura fisiológica (sem flexão ou extensão) da coluna é mantida durante os exercícios, mais esses músculos são recrutados. O método Pilates é eficaz no treinamento dos músculos do tronco em mulheres saudáveis.

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APÊNDICE 1 - TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

FACULDADE DE ODONTOLOGIA DE PIRACICABA

UNICAMP

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO (TCLE)
Número do CAAE: 64184216.9.0000.5418

APRESENTAÇÃO DA PESQUISA:

Você está sendo convidado a participar como voluntário da pesquisa ´´Avaliação dinamométrica e eletromiográfica dos músculos do core em praticantes e não praticantes de Pilates``, que será realizada na Unesp, campus de Rio Claro, sob a responsabilidade do sob responsabilidade da pesquisadora Ana Carolina Panhan, Doutoranda em Biologia Buco-Dental- FOP, Unicamp, Piracicaba; orientada pelo Prof. Dr. Fausto Bérzin. As informações presentes neste documento foram fornecidas pelos pesquisadores Ana Carolina Panhan e Fausto Bérzin que forneceram as informações para elaborar este termo. Este documento, chamado termo de Consentimento Livre e Esclarecido, visa assegurar seus direitos como participante e é elaborado em duas vias, uma que ficará com você e outra que ficará com o pesquisador.

Por favor, leia com atenção e calma, aproveitando para esclarecer suas dúvidas. Se tiver perguntas antes ou mesmo depois assinar o Termo, você poderá esclarecê-las com o pesquisador. Se preferir, você pode levar este Termo para casa e consultar seus familiares ou outras pessoas antes de decidir participar. Não haverá qualquer tipo de penalização ou prejuízo se você não quiser participar ou se retirar sua autorização em qualquer momento, mesmo depois de iniciar sua participação na pesquisa. É importante realizar esta pesquisa porque existe a necessidade de verificar se o método Pilates é eficiente para aumentar a ativação muscular dos estabilizadores e mobilizadores do tronco, portanto essa pesquisa buscará obter informações sobre o comportamento dos músculos do tronco em praticantes e não praticantes de Pilates.

INFORMAÇÕES SOBRE A PESQUISA:

Objetivos: O objetivo desta pesquisa será avaliar o perfil isocinético e eletromiográfico dos músculos flexores e extensores do tronco durante a realização do teste no dinamômetro isocinético, a resistência muscular e o equilíbrio de indivíduos com e sem experiência prévia com o método Pilates após quatro e oito semanas de treinamento, além de analisar a atividade eletromiográfica (EMG) dos músculos estabilizadores do tronco durante a realização do exercício *single leg stretch* em diferentes bases de apoio (solo e caixa) e exercícios realizados em equipamento (*wunda chair*).

Procedimentos e metodologias (Grupo Pilates): Participando do estudo você está sendo convidado a realizar três dias de avaliações:

Avaliações do 1º Dia: Resistência e força dos músculos flexores e extensores de tronco

a) **Avaliação de força dos músculos do tronco:** as participantes serão avaliadas no dinamômetro *System* 4 PRO (Biodex®), com velocidade angular de 120 graus por segundo. Sentadas em uma cadeira, farão força para flexionar e estender o tronco.

b) **Avaliação de resistência dos músculos extensores de tronco (Teste de SORENSEN):** consiste em manter o tronco na posição horizontal sobre a prancha sueca, sem suporte e com os membros inferiores estabilizados. O teste será realizado uma única vez até a exaustão

c) **Avaliação de resistência prancha lateral:** a participante se manterá em decúbito lateral, elevará os quadris fora do chão para manter uma linha reta linha e sustentar-se em um cotovelo e seus pés. O braço não envolvido permanecerá cruzado frente ao peito, com a mão no ombro oposto. O teste termina quando os quadris voltarem para o chão.

Avaliações do 2º Dia: Avaliação eletromiográfica dos músculos flexores do tronco durante a execução do exercício single leg stretch em diferentes bases de apoio (solo e long box).

Single leg stretch: postura deitada (costas apoiadas), a cabeça e ombros fora do tapete, com uma perna estendida e a outra flexionada. Execução: com as mãos (uma sobre a outra) na região da canela a voluntária levará o joelho direito em direção ao tórax e realizará uma expiração, e após realizará o mesmo movimento com o joelho esquerdo juntamente com uma inspiração. Número de repetições: cinco.

Avaliações do 3º Dia: Avaliação eletromiográfica dos músculos flexores e extensores do tronco durante a realização de exercícios na wunda chair.

Table: a partcipante ficará sentada e com as mãos sobre o estofado da wunda chair e os dedos dos pés no pedal do equipamento. Elevará o quadril, tentando manter uma linha contínua entre ombro, tronco e quadril. Com o quadril elevado o voluntário empurrará o pedal para cima e para baixo, sem movimentar os braços.

Going Up Front: a participante apoiará o pé direito sobre o estofado da wunda chair e os dedos do pé esquerdo sobre o pedal do equipamento. Fará os movimentos de elevar e abaixar o pedal.

Montain Climb: a participante apoiará o pé direito sobre o estofado da wunda chair e os dedos do pé esquerdo sobre o pedal do equipamento. O joelho da perna direita se manterá flexionado durante todo o exercício e a perna esquerda empurrará o pedal para baixo e depois para cima.

Swan Dive: a partcipante deverá estar com o abdome apoiado no estofado da wunda chair, e mãos em contato como o pedal do equipamento. Joelhos e coxas estendidos e tornozelos unidos. A voluntária deverá empurrar o pedal para baixo e elevar o tronco para cima realizando uma extensão da coluna vertebral.

Procedimentos e metodologias (Grupo Controle e Bailarinas): Participando do estudo você está sendo convidado a realizar os seguintes procedimentos:

Aulas de Pilates: O protocolo de treinamento com o método Pilates terá duração de oito semanas (duas vezes por semana e 45 minutos de duração) e as respectivas avaliações serão realizadas em três momentos: antes do treinamento, após quatro semanas de treinamento e após oito semanas de treinamento.

Serão mensuradas a massa e a estatura, além da mensuração de valores de dobras cutâneas, para obtenção do percentual de gordura. Testes:

Avaliação de equilíbrio, força, resistência dos músculos flexores e extensores do tronco

c) Avaliação de força dos músculos do tronco: as participantes serão avaliadas no dinamômetro System 4 PRO (Biodex®), com velocidade angular de 120 graus por segundo. Sentadas em uma cadeira, farão força para flexionar e estender o tronco.

d) Avaliação de resistência dos músculos extensores de tronco (Teste de SORENSEN): consiste em manter o tronco na posição horizontal sobre a prancha sueca, sem suporte e com os membros inferiores estabilizados. O teste será realizado uma única vez até a exaustão

c) Avaliação de resistência prancha lateral: a participante se manterá em decúbito lateral, elevará os quadris fora do chão para manter uma linha reta linha e sustentar-se em um cotovelo e seus pés. O braço não envolvido permanecerá cruzado frente ao peito, com a mão no ombro oposto. O teste termina quando os quadris voltarem para o chão.

d) Avaliação do equilíbrio: As participantes serão instruídas a posicionarem-se sobre a plataforma de força com o pé direito apoiado sobre a mesma e o pé contralateral fora dela, cabeça alinhada horizontalmente com os olhos focando um ponto fixo a sua frente, o teste terá duração de 30 segundos.

Você **não** deve participar deste estudo se tiver apresentado lesões e dores na região da coluna lombar por no mínimo seis meses anteriores aos testes, além disso, não podem apresentar desvios posturais graves, como por exemplo: hipercifose, hiperlordose e escoliose.

Desconfortos e riscos previstos: Os possíveis riscos da coleta são aqueles inerentes a qualquer prática de exercícios extenuantes, que podem ser hipotensão, hipoglicemia, ou mal estar (náuseas e vômitos), que ocorrem com pouca frequência e retornam à normalidade após alguns minutos, raramente necessitando de procedimentos para reverter este quadro. Outro risco seria o do aparecimento de dores resultantes de um processo inflamatório normal que acontece para a reestruturação do tecido danificado. Essas dores devem passar em um período de 2 a 4 dias. Estes riscos podem ser esclarecidos a qualquer momento pelo responsável dos testes, e tendem a ser minimizados pelas condições de pronto atendimento em caso de acidente, que envolve o chamado da Unidade de Resgate do Corpo de Bombeiros, com equipamentos médicos e motorista, auxiliar e encarregado para a realização dos primeiros socorros. Devido à necessidade de avaliação da massa, estatura e mensuração de valores de dobras cutâneas, para obtenção do percentual de gordura, esta avaliação pode gerar constrangimento aos participantes. Esta possibilidade será atenuada pelo fato desta avaliação ser realizada em ambiente fechado e conduzida por apenas avaliadores envolvidos no experimento, sem presença de outras pessoas no momento da avaliação.

Benefícios: Essa pesquisa terá como principais benefícios mostrar aos participantes a partir dos resultados individuais como é o seu desempenho durante os testes de força, equilíbrio e resistência muscular e a partir disso, poderá tentar melhorar as capacidades físicas avaliadas. Os resultados obtidos serão enviados para as participantes individualmente por e mail.

Acompanhamento e assistência: O Pesquisador será responsável por acompanhar os participantes durante as coletas e após as mesmas se houver necessidade, já que a pesquisa não fornece riscos graves aos participantes.

Forma de contato com os pesquisadores: Em caso de dúvidas sobre a pesquisa, você poderá entrar em contato com a pesquisadora Ana Carolina Panhan, através do endereço Av. 24 A, 1515, Bela Vista, Rio Claro (Laboratório de Biomecânica da Unesp) telefone (19) 992972026 ou pelo e mail carol_panhan@hotmail.com.

Forma de contato com Comitê de Ética em Pesquisa (CEP): O papel do CEP é avaliar e acompanhar os aspectos éticos das pesquisas envolvendo seres humanos, protegendo os participantes em seus direito e dignidade. **Em caso de dúvidas, denúncias ou reclamações sobre sua participação e sobre seus direitos como participante da pesquisa, entre em contato com a secretaria do Comitê de Ética em Pesquisa (CEP)** da Faculdade de

Odontologia de Piracicaba/UNICAMP: Av Limeira 901, FOP-Unicamp, CEP 13414-903, Piracicaba – SP. Fone/Fax 19-2106.5349, e-mail cep@fop.unicamp.br e Web Page www.fop.unicamp.br/cep.

GARANTIAS AOS PARTICIPANTES:

Esclarecimentos: Você será informado e esclarecido sobre os aspectos relevantes da pesquisa, antes, durante e depois da pesquisa, mesmo se esta informação causar sua recusa na participação ou sua saída da pesquisa.

Direito de recusa a participar e direito de retirada do consentimento: Você tem o direito de se recusar a participar da pesquisa e de desistir e retirar o seu consentimento em qualquer momento da pesquisa sem que isso traga qualquer penalidade ou represálias de qualquer natureza e sem que haja prejuízo ao seu tratamento iniciado ou por iniciar

Sigilo e privacidade: Você tem a garantia de que sua identidade será mantida em sigilo e as informações obtidas durante a pesquisa só serão acessadas pelos pesquisadores. Na divulgação dos resultados desse estudo, informações que possam identificá-lo não serão mostradas ou publicadas.

Ressarcimento: Essa pesquisa não acarretará nenhum tipo de despesa e também não oferecerá remuneração para participar da mesma.

Indenização e medidas de reparação: Não há previsão de indenização ou de medidas de reparo, pois não há previsão de risco ou de dano potenciais pela participação na pesquisa, mas você tem o direito de buscar indenização e reparação se se sentir prejudicado pela participação na pesquisa.

Entrega de via do TCLE: Você receberá uma via deste Termo assinada e rubricada pelo pesquisador.

CONSENTIMENTO LIVRE E ESCLARECIDO:

Após ter recebido esclarecimentos sobre a natureza da pesquisa, seus objetivos, métodos, benefícios previstos, potenciais riscos e desconfortos que esta pode acarretar, aceito participar e declaro ter recebido uma via original deste documento rubricada em todas as folhas e assinada ao final, pelo pesquisador e por mim:

Nome do (a) participante:

____

Contato telefônico: ____

e-mail (opcional): ____

________________________________Data: ____/_____/______.

(Assinatura do participante)

Responsabilidade do Pesquisador:

Asseguro ter cumprido as exigências da resolução 466/2012 CNS/MS e complementares na elaboração do protocolo e na obtenção deste Termo de Consentimento Livre e Esclarecido. Asseguro, também, ter explicado e fornecido uma via deste documento ao participante. Informo que o estudo foi aprovado pelo CEP perante o qual o projeto foi apresentado e pela CONEP, quando pertinente. Comprometo-me a utilizar o material e os dados obtidos nesta pesquisa exclusivamente para as finalidades previstas neste documento ou conforme o consentimento dado pelo participante.

________________________________Data: ____/_____/______.

(Assinatura do participante)

ANEXO 1 – PARECER CONSUBSTANCIADO DO CEP

UNICAMP - FACULDADE DE
ODONTOLOGIA DE
PIRACICABA DA

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: Avaliação dinamométrica e eletromiográfica dos músculos do core em praticantes e não praticantes de Pilates

Pesquisador: Ana Carolina Panhan

Área Temática:

Versão: 8

CAAE: 64184216.9.0000.5418

Instituição Proponente: Faculdade de Odontologia de Piracicaba - Unicamp

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.262.420

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

ANEXO 2 – CARTA DE ACEITE: ARTIGO 1

From: Kathi Kemper

To: Ana Carolina Panhan

Subject: Your manuscript CTIM_2018_457_R1 has been accepted

Ref: CTIM_2018_457_R1
Title: NEUROMUSCULAR EFFICIENCY OF THE MULTIFIDUS MUSCLE IN PILATES PRACTITIONERS AND NON-PRACTITIONERS
Journal: Complementary Therapies in Medicine

Dear Miss. Panhan,

I am pleased to inform you that your paper has been accepted for publication. My own comments as well as any reviewer comments are appended to the end of this letter. Now that your manuscript has been accepted for publication it will proceed to copy-editing and production.

Thank you for submitting your work to Complementary Therapies in Medicine. We hope you consider us again for future submissions.

Kind regards,

Kathi Kemper, MD, MPH
Editor-in-Chief
Complementary Therapies in Medicine

ANEXO 3 – CARTA DE ACEITE: ARTIGO 2

Date: Mar 29, 2019
To: "Ana Carolina Panhan" carol_panhan@hotmail.com
From: "JBMT Editorial Team" editorjbmt@gmail.com
Subject: Your Submission

Ref.: Ms. No. YJBMT-D-19-00141
"Electromyographic evaluation of trunk core muscles during Pilates exercise on different supporting bases."
Journal of Bodywork & Movement Therapies

Dear Panhan,

I am pleased to tell you that your work has now been accepted for publication in Journal of Bodywork & Movement Therapies.

It was accepted on Mar 29, 2019

Thank you for submitting your work to this journal.

With kind regards

Sasha Chaitow, PhD
Managing Editor
Journal of Bodywork & Movement Therapies

ANEXO 4 – CARTA DE ACEITE: ARTIGO 3

Journal of Back and Musculoskeletal Rehabilitation

MANUSCRIPT 18-1267-R

"CO-CONTRACTION OF THE CORE MUSCLES DURING PILATES EXERCISE ON THE WUNDA CHAIR"

DECISION LETTER

Your manuscript (18-1267-R) has been accepted in the Journal of Back and Musculoskeletal Rehabilitation.

Please complete the required BMR Author Publication Fee Order form:
http://www.iospress.nl/journal-fee-form/?id=14&journal=29299.

If you experience any problems with the payment, please contact
Authorfees@iospress.nl.

More information is available at our website:
http://www.iospress.nl/journal/journal-of-back-and-musculoskeletal-rehabilitation/?tab=manuscript-submission.

When it is ready to be published, you will receive digital proofs from the publisher prior to publication. You should check these proofs carefully and return them to the typesetter within three (3) days.

Thank you for your contribution, and we look forward to receiving further submissions from you in the future.

Yours sincerely,

Prof. Hermie J. Hermens	Mrs. Hester Watson
Editor-In-Chief	Editorial Assistant

Journal of Back and Musculoskeletal Rehabilitation

ANEXO 5 – RELATÓRIO DE SIMILARIDADE

Avaliação dinamometrica e eketromiografica Dos músculos do cire

RELATÓRIO DE ORIGINALIDADE

26%	0%	26%	0%
ÍNDICE DE SEMELHANÇA	FONTES DA INTERNET	PUBLICAÇÕES	DOCUMENTOS DOS ALUNOS

FONTES PRIMÁRIAS

1	Ana C. Panhan, Mauro Gonçalves, Giovana D. Eltz, Marina M. Villalba, Adalgiso C. Cardozo, Fausto Bérzin. "Electromyographic evaluation of trunk core muscles during Pilates exercise on different supporting bases", Journal of Bodywork and Movement Therapies, 2019 Publicação	14%
2	Ana Carolina Panhan, Mauro Gonçalves, Giovana Duarte Eltz, Marina Mello Villalba, Adalgiso Coscrato Cardozo, Fausto Bérzin. "Co-contraction of the core muscles during Pilates exercise on the Wunda Chair", Journal of Back and Musculoskeletal Rehabilitation, 2019 Publicação	10%
3	Ana C. Panhan, Mauro Gonçalves, Giovana D. Eltz, Marina M. Villalba, Adalgiso C. Cardozo, Fausto Bérzin. "Neuromuscular efficiency of the multifidus muscle in pilates practitioners and non-practitioners", Complementary Therapies in Medicine, 2018 Publicação	2%

ANEXO 6 - NOTA DE JUSTIFICATICA PARA O RELATÓRIO DE SIMILARIDADE

Após o relatório de similaridade apresentado pelo Turnitin, os valores desmontrados pelo mesmo são justificados pelo fato de que os três artigos que fazem parte dessa tese já terem sido anteriormente publicados.

Segue os links abaixo das respectivas revistas e artigos completos:

Artigo 1:

https://www.sciencedirect.com/science/article/abs/pii/S0965229918304850?via%3Dihub

Artigo 2:

https://www.bodyworkmovementtherapies.com/article/S1360-8592(19)30109-3/fulltext

Artigo 3:

https://content.iospress.com/articles/journal-of-back-and-musculoskeletal-rehabilitation/bmr181267?resultNumber=0&totalResults=1&start=0&q=PANHAN&resultsPageSize=10&rows=10