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original article

A comparative analysis of the electrical activity of the abdominal muscles during traditional and Pilates-based exercises under two conditions

Análise comparativa da atividade elétrica dos músculos abdominais durante exercício tradicional e método pilates sob duas condições

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Abstract – The use of Pilates-based exercises for trunk strengthening has been reported in the literature. The objective of this study was to analyze and compare the electrical activity of the rectus abdominis and external oblique muscles during a traditional abdominal exercise program and an exercise program based on the Pilates method using a ball and an elastic band. The sample was composed of 10 healthy women, non-practitioners of Pilates, who performed the traditional abdominal exercise and roll-up with the ball and elastic band. The sign was normalized by the electromyographic peak of the dynamic activity and was adjusted for 2000 samples/s; the filter was set in a frequency band from 20 to 450 Hz. In the comparison between exercises, the external oblique muscle in the concentric phase had a higher recruitment in the roll-up with the ball ($P = 0.042$). In the comparison between muscles in each exercise, the rectus abdominis showed a higher activation in the concentric phase ($P = 0.009$) and in the eccentric phase ($P = 0.05$) of the traditional abdominal exercise. Activation percentages ranged from 15% to 22%. The traditional abdominal exercise had the largest activation percentage.

Key words: Abdominal muscles; Electromyography; Exercise; Physical therapy.

Resumo – *Exercícios baseados no método Pilates são relatados na literatura para serem utilizados como proposta de fortalecimento de tronco. O objetivo deste estudo foi analisar e comparar a atividade elétrica dos músculos reto abdominal e oblíquo externo, durante um exercício de abdominal tradicional e um exercício baseado no método Pilates com bola e com faixa elástica. A amostra foi composta por 10 mulheres saudáveis não praticantes de Pilates, que realizaram o exercício de abdominal tradicional e Roll-up com bola e faixa elástica. O sinal foi normalizado pelo pico eletromiográfico da atividade dinâmica e foram ajustados para 2000 amostras por segundo e o filtro em uma frequência de passagem de 20 a 450 Hz. Na comparação entre exercícios, o músculo oblíquo externo na fase concêntrica teve maior recrutamento no Roll-up com bola (P = 0,042). Na comparação entre os músculos em cada exercício, o reto abdominal teve maior ativação nas fases concêntrica (P = 0,009) e excêntrica (P = 0,05) do abdominal tradicional. As porcentagens de ativação variaram de 15% a 22%. O exercício de abdominal tradicional teve a maior porcentagem de ativação.*

Palavras-chave: *Eletromiografia; Exercício; Fisioterapia; Músculos abdominais.*

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INTRODUCTION

The abdominal muscles are of great importance in the movement of the trunk and in spine stabilization. In fact, these are considered to be the most important functions of these muscles[1]. Lack of conditioning can cause a decrease in endurance and strength, which leads to biomechanical changes and pain conditions. Evidence suggests benefits of the inclusion of strengthening exercises for the muscles involved in trunk flexion in prevention programs and the treatment of low back pain[2,3]. There are several exercises described for the strengthening of trunk flexors, such as the traditional curl-up on the horizontal and inclined plane, elevation of extremities, as well as methods like Iso Stretching, Global Postural Reeducation and Pilates[3,4].

The Pilates method was developed by Joseph H. Pilates and involves specific training of the trunk stabilizer muscles, including the abdominals (rectus abdominis, internal oblique, external oblique and transversus abdominis) to increase muscle tone and strength beyond the dynamic control of the muscles[5]. Pilates-based exercises are described in the literature and have been adapted and simplified from the traditional method to be used in clinical propositions[6]. The exercises can be performed on floor mats, on apparatus or even with equipment like the Swiss ball and elastic bands[7].

The eletromyographic comparison of trunk stabilizer muscles during Pilates exercises has been recently reported in the literature[8-10]. Esco et al.[8] evaluated the electrical activity of the rectus abdominis, external obliques and rectus femoris during the Pilates exercises the hundred, criss-cross, double-leg stretch, roll-up and teaser, and compared them to the traditional curl-up. The results showed that the Pilates exercises recruited the abdominal muscles well enough to promote conditioning. Some authors demonstrate that the rectus abdominis muscle has a lower activation during Pilates exercises compared to other muscles, such as the external oblique[9]. Studies point out that muscles have distinct electrical activations according to the individual's position or the condition in which the exercise is performed (mat or apparatus)[9,10].

Existing studies mainly evaluate individuals who are already practicing the Pilates method, however, there has been a remarkable increase in thesearch for Pilates based exercises carried out by sedentary individuals,which makes the prescription of exercise by professionals for this population more frequent, often as a convenience. In addition, there are a scarcity of studies designed to compare Pilates-based exercises to the traditional curl-up and to analyze electromyographic (EMG) activation in people who are new to the method. Thus, the aim of this study was to compare and to analyze EMG activation of the rectus abdominis and external oblique muscles of non Pilates practitioners during a traditional trunk flexion exercise (curl-up) and during roll-up (basic Pilates mat exercise) using a ball and an elastic band.

METHODS

SAMPLE

The sample consisted of 10 women with a mean age of 21.5 years (SD = 0.64) and a body mass index (BMI) of 19.6 kg/m^2 (SD = 0.4), healthy and non-practitioners of Pilates. The exclusion criteria were: regular practice of physical activity, low back pain, intervertebral disc protrusion, previous column or abdominal surgery, spondylolisthesis, scoliosis, neurological diseases, infectious diseases, cancer and pregnancy. The study was approved by the Ethics Committee of the Universidade Estadual de Londrina (CEP 266/07) and the participants signed an informed consent form.

PROCEDURES

A 16-channel EMG system (MP150; BIOPAC Systems Inc, Aero Camino Goleta, CA), consisting of an A-D converter of 16 bits, an input range of ± 10 volts, an amplifier gain of 2000 and a common mode rejection ratio of more than 120 dB was used to obtain the biological signals. The frequency of acquisition of signals was set to 2000 samples per second, with a signal conditioner with a Butterworth filter of 9th order and cutoff frequency of 20 to 450 Hz. Active bipolar electrodes, with an interelectrode distance of 2 cm, were positioned on the rectus abdominis (three cm lateral of the umbilicus) and external oblique (center distance between the anterior superior iliac spine and the lower edge of the rib cage), following the direction of muscle fibers (Figure 1)[11]. The reference electrode was placed on the ulnar styloid process. A 30 Hz video camera (Sony) was used for synchronizing the execution of the exercise in order to identify concentric and eccentric phases. For the execution of the exercises a 65 cm Swiss ball and a purple elastic band (Carci) were used, standardized for all participants.

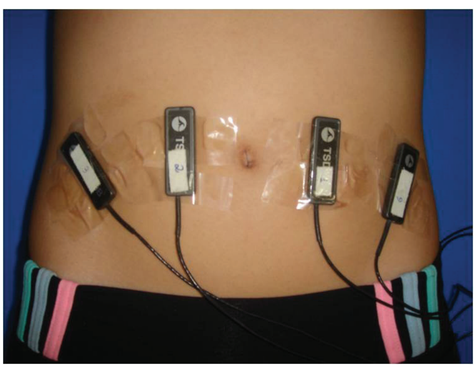

Figure 1. Electrodes in place

Prior to the execution of the exercises, the participants performed three warm up exercises of eight repetitions each: breathing, spine stretch and ab prep. The signals were collected during three repetitions of the following exercises: traditional curl-up (Figure 2-A), roll-up based on the Pilates method with a ball (Figure 2-B) and with an elastic band (Figure 2-C), with a rest of five minutes between exercises. All participants underwent familiarization exercises before the trial, and the order collection was made by means of a simple draw.

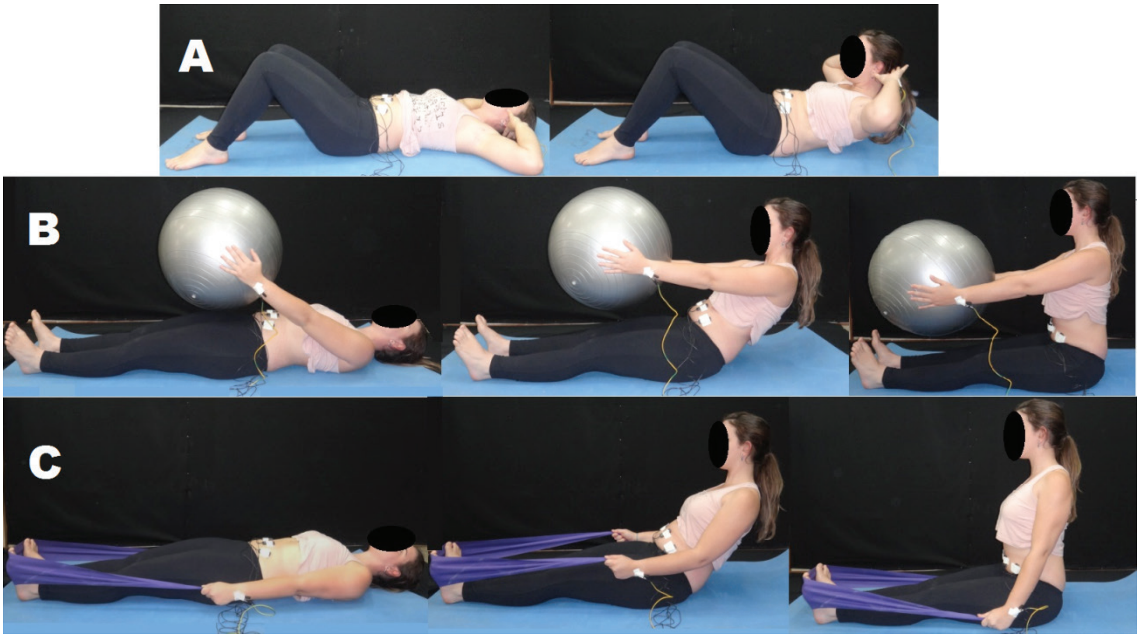

Figure 2. Traditional curl-up (A), roll-up with ball (B) and roll-up with elastic band (C).

The data were interpreted in the AcqKnowledge 3.9.1 software and processed using subroutines in Matlab (version 7.7.0). The EMG signal was normalized by the peak of dynamic activity. Values are given in percentage activation of RMS (root mean square), expressed in milivolts (mV) for each muscle, exercise and phase.

Statistical analysis

Normality was verified using the Shapiro-Wilk test. The analysis of variance for repeated measures (ANOVA) was used to examine differences between the right and left sides, between the concentric and eccentric phases and between exercises. The W. Mauchly test of sphericity was applied and when it was violated, technical corrections were made using the Greenhouse-Geisser test. When the F test was significant, the analysis using the multiple comparison test of Tukey was applied. Significance was set at 5% ($P \leq 0.05$).

RESULTS

There was no difference between the right and left sides of the rectus abdominis and external oblique and between phases (concentric and eccentric), thus, the values of the right side were considered. Comparing exercises, a statistically significant difference in % RMS for the external oblique muscle was found (Table 1).

Table 1. Comparison of % of RMS values (mV) between exercises in the concentric phase

	Condition			P		
Muscle	Curl up mean (SD)	Roll-up ball mean (SD)	Roll-up band mean (SD)	P1	P2	P3
RA	22.68 (2.55)	18.30 (1.47)	21.61 (2.86)	0.076	1.000	0.360
EO	15.28 (2.15)	17.48 (2.51)	18.54 (2.93)	0.042	0.134	1.000

RA (rectus abdominis), EO (external oblique), P1 = (curl-up x ball), P2 = (curl up x band), P3 = (ball x band), SD = standard devitation.

Comparing the muscles in each exercise, significant differences were found in the % of RMS in favor of the rectus abdominis, compared to the external oblique in both the concentric and the eccentric phase of the traditional curl-up exercise (Table 2).

Table 2. Comparison of % of RMS values (mV) between muscles for each exercise.

Muscle_Exercise_Phase	$\bar{x}$ (SD)	P
RA_curl-up_concentric phase	22.68 (8.09)	0.009
EO_curl-up_concentric phase	15.28 (6.81)	
RA_ball_ concentric phase	18.30 (4.66)	0.680
EO_ball_ concentric phase	17,48 (7.93)	
RA_band_ concentric phase	21.61 (9.05)	0.189
EO_band_ concentric phase	18.54 (9.28)	
RA_ curl-up_eccentric phase	22.57 (11.83)	0.050
EO_ curl-up_eccentric phase	14.77 (5.81)	
RA_ball_eccentric phase	16.70 (3.86)	0.765
EO_ball_eccentric phase	16.00 (8.31)	
RA_band_eccentric phase	17.98 (5.15)	0.823
EO_band_eccentric phase	17.32 (9.85)	

RA (rectus abdominis), EO (external oblique), SD = standard deviation.

The variation in percentages of activation was approximately between 14% and 22%, with a greater recruitment of the rectus abdominis during the traditional curl-up exercise, in both the concentric and eccentric phase. During the roll-up exercise with the elastic band, a statistically significant difference in the percentage of activation in favor of the external oblique muscle (17%) was found, when compared to the rectus abdominis in the eccentric phase ($P = 0.007$).

DISCUSSION

The electrical activity of the abdominal muscles during the curl-up exercise has been discussed for a long time[12,13]. Recent studies have sought to evaluate the muscle behavior during the execution of Pilates exercises[14,15]. Menacho et al.[14] analyzed the trunk extensor muscles (multifidus) for three Pilates mat exercises through surface EMG. Dorado et al.[15] demonstrated, using an MRI, that a Pilates program of exercises can increase the total volume of the rectus abdominis muscle by 21% in sedentary women who are non practitioners of Pilates.

The results of this study suggest that the obliques showed greater activation when comparing the RMS values during the concentric phase of the roll-up exercise with the ball. The activity of holding the ball in the exercise in question causes greater resistance to the upper limbs and trunk, thus, the obliques act in order to avoid excessive elevation of the rib cage[16]. In addition, the positioning of the pelvis and the amplitude and direction of movement require trunk stabilization during the exercise and the external oblique muscle contributes to this activity[17,18].

Floyd e Silver[12] demonstrated that the rectus abdominis has a higher electrical activity when compared to the obliques in cervical flexion exercises by being the primary muscle of trunk flexion. When considering the biomechanics of the traditional curl-up exercise, it requires greater control of the rectus abdominis in order to be performed with the upper limbs above the head, while in the roll-up, the arms are positioned at approximately 30° of shoulder flexion[13]. Moreover, the weight of the ball and elastic band resistance can help control the movement of trunk flexion in both phases, which may explain the higher electrical activity of the abdominal muscles during traditional exercise.

Studies[17-20] showed that the traditional curl-up exercise is able to generate more activation of the rectus abdominis muscle, when compared to other exercises to strengthen the abdominal muscles. The rectus abdominis muscle is responsible for the first 30° to 45° of trunk flexion, and moves above this angle require limited function of these muscles[1,21].

In this study, the variation in percentages of activation was between 15% and 22%, with a greater recruitment of the rectus abdominis during the traditional curl-up exercise. For the same exercise, different percentages of activation were found. Esco et al.[8] evaluated the roll-up and traditional curl-up and found an activation of 75% for the rectus abdominis and 70% for the external oblique during the roll-up and 54% for the rectum and 19% for the oblique during traditional exercise. Escamilla et al.[18]pointed out an activation of 39% for the rectus abdominis and 28% for the external oblique, Escamilla et al.[17] found a 50% activation of the rectus abdominis and 16% for the external oblique and Konrad et al.[22] an activation of 51% for the rectus abdominis and 28% for the external oblique. For the classification of muscular activity, a study considers 0-20% to be low activity, 20 to 40% moderate activity, 41 to 60% high activity and more than 60% very high activity[23].

However, it must be considered that the studies cited above performed EMG signal normalization using MVIC, while in this one, the normalization was performed by EMG peak of dynamic activity. Studies suggest that the ability to maximally activate all motor units to perform the MVIC depends on many factors, including training and motivation. Untrained individuals can generate a force of 20-40% less than the maximum[24] or overestimate the actual MVIC, yielding a MVIC above 100%[19]. Furthermore, dynamic exercises use numerous muscles simultaneously, changing their length-tension relationship and consequently the EMG activity during movement[26]. Additionally, different individuals do not have the same ability for muscle activation in certain exercises, which makes interpretation of the data subject to interindividual variability when normalized by MVIC[27,28]. Because of this, the normalization by peak of dynamic activity should be preferred as a method of evaluating proposals of muscle activity in dynamic exercises[29].

The results showed that the traditional abdominal exercise causes increased activity when compared to the Pilates-based roll-up exercise. In a recent systematic review, the authors concluded that Pilates-based exercises are not more effective than a minimal intervention or other exercises used to reduce dysfunction caused by low back pain[6]. However, a recent randomized controlled trial[30] suggests that the method should be used as an adjuvant to improve motor control and flexibility of the trunk and pelvis. In clinical practice, there is a pre-established sequence of exercises chosen by the physical therapist. Future studies are warranted to conduct EMG evaluations during a sequence of Pilates exercises (mat, use of accessories and/or equipment) as well as to compare EMG patterns in people adapted and not adapted to the method.

CONCLUSION

The results found in this study suggest that the traditional curl-up causes an increased activity of these muscles when compared to Pilates-based exercises. Furthermore, the importance of the external oblique muscle in stabilizing the rib cage in exercises that use the upper limbs is evident. This fact should be considered when prescribing clinical programs, depending on professional assessment and treatment goal.

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