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Respiratory muscle performance after 12 sessions of training using the apparatus Reformer of Pilates method

Desempenho muscular respiratório após 12 sessões de treinamento utilizando o aparelho Reformer *do método Pilates*

Rendimiento muscular respiratorio después de 12 sesiones de entrenamiento utilizando el aparato Reformer del método Pilates

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ABSTRACT | To analyze respiratory muscle performance in exercise practitioners using the Reformer of Pilates method after a 12-session training. This study was carried out with 24 volunteers, healthy young adults, non-smokers and non-regular exercisers, divided into control group (CG) and trained group (TG). The TG participated in a training program executing 6 exercises in the Reformer apparatus. Both groups were submitted to the initial and final evaluations to analyze the performance of the respiratory muscles through the manovacuometry and electromyography of the rectus abdominis muscle. The Shapiro-Wilk test was used to verify the data normality. Two-way analysis of variance was used for the comparisons between the groups (TG and CG) and moments (Initial and Final). For multiple comparisons, the Scheffé post hoc test was used. The groups Control and Trained were paired by age and BMI by paired t test. P <0.05 was considered for significance. A significant difference (p=0039) was observed between the initial (116.6 ± 12.8) and final (120 ± 12.8) values of MIP in the trained group, as well as between baseline values (75.3 ± 12.4) and final (89.3 ± 13.7) of MEP in the same group (p=0.0005). For electromyography, a significant difference (p=0.03) was observed between the initial (42.1 ± 15.8) and final (76.7 ± 37.1) moments of the TG for the left rectus abdominis muscle. The conclusion is that the 12 Pilates sessions using the Reformer apparatus improve respiratory muscle performance, increasing the inspiratory and expiratory muscle strength.

Keywords | Exercise and Movement Techniques; Respiratory Muscles; Electromyography.

RESUMO | Analisar o desempenho muscular respiratório em praticantes de exercícios utilizando o aparelho *Reformer* do Método Pilates após um treinamento de 12 sessões. O estudo foi realizado com 24 voluntárias, adultas jovens, saudáveis, não tabagistas e não praticantes de exercício físico regular, divididas em Grupo Controle (GC) e Grupo Treinado (GT). Os dois grupos foram submetidos às avaliações inicial e final para análise do desempenho dos músculos respiratórios por meio da manovacuometria e da eletromiografia do músculo reto abdominal. Utilizou-se o teste de *Shapiro-Wilk* para verificar a normalidade dos dados. A análise

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Corresponding address: Lara Andrade Souza – Rua Olegário Maciel, 144, apto 1204 – Uberaba (MG), Brazil – Zip Code: 38010-230 – E-mail: lara.asouza@yahoo.com.br – Finance source: CAPES; FAPEMIG and CNPq – Conflict of Interests: Nothing to declare – Presentation: Feb. 7th, 2018 – Accepted for publication: Jan. 15th, 2019 – Approved by the Comitê de Ética em Pesquisa (CEP)/UFTM: Protocolo nº 2406.

de variância *two-way* foi empregada para as comparações entre os grupos (GT e GC) e os momentos (inicial e final). Para comparações múltiplas, utilizou-se o teste post-hoc de Scheffé. Os GC e GT foram pareados para idade e IMC e, para verificação de diferenças entre os grupos, utilizou-se o teste t pareado. Considerou-se p<0,05 para significância. Houve diferença significante (p=0,039) entre os valores iniciais (116,6 ± 12,8) e finais (120 ± 12,8) de PImáx no GT, assim como entre os valores iniciais (75,3 ± 12,4) e finais (89,3 ± 13,7) de PEmáx nesse mesmo grupo (p=0,0005). Para a eletromiografia houve diferença significante (p=0,03) entre o momento inicial (42,1 ± 15,8) e final (76,7 ± 37,1) do GT para o músculo reto abdominal esquerdo. Conclui-se que as doze sessões de Pilates utilizando o aparelho *Reformer* melhoraram o desempenho muscular respiratório, aumentando a força da musculatura inspiratória e expiratória.
Descritores | Técnicas de Exercício e Movimento; Músculos Respiratórios; Eletromiografia.

RESUMEN | Evaluar el rendimiento de los músculos respiratorios en practicantes de ejercicios utilizando el método *Reformer* de Pilates después de un entrenamiento de 12 sesiones. Este estudio se realizó con 24 voluntarios, adultos jóvenes, sanos, no fumadores y no deportistas regulares, siendo divididos en grupo control (GC) y grupo entrenado (GE). El GE participó en un programa de entrenamiento ejecutando 6 ejercicios en el aparato *Reformer*. Ambos grupos se sometieron a evaluaciones iniciales y finales para analizar el rendimiento de los músculos respiratorios mediante la manovacuometría y la electromiografía del músculo recto abdominal. La prueba de *Shapiro-Wilk* se utilizó para verificar la normalidad de los datos. Se utilizó el análisis de varianza *two-way* para las comparaciones entre los grupos (GE y GC) y los momentos (inicial y final). Para comparaciones múltiples, se utilizó la prueba post-hoc de Scheffé. El GC y el GE se emparejaron por edad e IMC mediante la prueba t pareada. Se consideró el valor de significación p<0,05. Se observó una diferencia significativa (p=0,039) entre los valores iniciales (116,6 ± 12,8) y finales (120 ± 12,8) de PImax en el grupo entrenado, así como entre los valores de iniciales (75,3 ± 12,4) y finales (89,3 ± 13,7) de PEmax en el mismo grupo (p=0,0005). En la electromiografía, se observó una diferencia significativa (p=0,03) entre los momentos inicial (42,1 ± 15,8) y final (76,7 ± 37,1) del GE para el músculo recto abdominal izquierdo. Se concluye que las 12 sesiones de Pilates utilizando el aparato *Reformer* mejoran el rendimiento de los músculos respiratorios, aumentando la fuerza muscular inspiratoria y espiratoria.
Palabras clave | Técnicas de Ejercicio y Movimiento; Músculos Respiratorios; Electromiografía.

INTRODUCTION

The Pilates method (PM), developed by Joseph Pilates, who called it "Contrology", is a system of physical conditioning that has six principles: concentration, control, precision, centering, breath and fluid movement[1].

The PM can be practiced on the ground or using devices, and Reformer is one of them. It has a rectangular structure on which a carriage is pushed, with a riser adjustment knob for supporting the feet or hands and five springs responsible for offering resistance to movement[2].

During the PM exercises, the training of the respiratory muscle is constant, working both resistance and strength[3]. The method prioritizes the lateral expansion of the rib cage and thus influences the lung volumes[4]. It can act in the abdominal-thoracic mobility, through the breathing pattern set[5], promoting intense recruitment of the transversus abdominis muscle and the internal oblique muscle, especially when the breathing pattern is associated with the trunk movement[6].

The PM has been growing in popularity, but the literature is still scarce concerning its benefits to the respiratory system. It is a relevant investigation, considering the focus given to the respiratory control in this methodology of physical exercises[7]. Salvadeo et al.[5] also propose that studies focused on the understanding of the physiology of the PM in different body systems must be carried out, endorsing the rise and prominence of such methodology.

One believes that a protocol of physical exercises based on the PM provides increased respiratory muscle performance. Therefore, this study aimed to analyze the performance and electrical activity of the rectus abdominis muscle in exercise practitioners that used the Reformer apparatus of the PM after 12 sessions.

METHODOLOGY

Study Design

This is a quantitative study, with a longitudinal and descriptive design.

Subjects

The non-probability sample was composed of 24 female volunteers, aged between 21 and 34 years, healthy, non-smokers, non-regular exercisers and beginners in the PM.

This study followed all ethical precepts, being approved by the Research Ethics Committee of the Universidade Federal do Triângulo Mineiro (UFTM), under number 2406.

The participants were divided into two groups: trained group (TG, n=12) and control group (CG, n=12). The distribution followed the order of acceptance of participation in the study, alternating between TG and CG. The study was conducted in a lab from UFTM.

Data Collection

The body mass (kg) and height (m) were measured, and the value of body mass index was calculated (BMI, in kg/m^2). For this purpose, a Balmak digital scale, class III, with a capacity of 150 kg and division of 50g for body mass, capacity of 2 m and 0.5 m for height, was used.

Both groups were subjected to initial and final assessments. The maximum inspiratory pressure (MIP) and the maximum expiratory pressure (MEP) were measured, using a digital manovacuometer, brand Comercial Médica, with a scale from -120 to + $120cmH_2O$ and division of $4cmH_2O$. All measures were taken by the same researcher and carried out through homogeneous verbal command, with the volunteers sitting, their feet on the ground, their nose occluded by a nose clip to prevent the air from escaping, and keeping a mouthpiece between their lips[8]. The MIP was measured during effort started from the residual volume, and the MEP from the total lung capacity. Each volunteer performed three efforts of inspiration and expiration, technically satisfactory, considering the largest value obtained for the analysis of this study[9-11]. The values of MIP and MEP predicted were calculated according to Neder et al.[12].

For analyzing the electrical activity of the rectus abdominis muscle, a Miotool 400USB four-channel electromyography (Miotec®), differential active sensors, Ag/AgCl square electrodes with 1 cm in diameter (MAXICOR®), 1000 x gain per channel, a 14-bit A/D converter, an acquisition rate of 1000 Hz per channel, common mode rejection ratio of 110db, noise level of <2 LSB (Low Significative Bit), and input impedance of 10^{10}Ohm//2pF were used. The signal was processed using the Miograph software (Miotec®), being filtered by a 20-500hz band-pass filter, 4th order Butterworth.

For the placement of electrodes, the skin preparation was carried out according to the recommendations of Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM)[13]. The electrodes were placed in the muscle belly bilaterally, in the direction of the muscle fibers, 1 cm above the navel and 2 cm to the abdomen midline[14]. The volunteers were put in supine position on a stretcher, with their knees semi-flexed, and told to make maximum voluntary isometric flexion of trunk against manual resistance imposed by the examiner in the shoulder region, preventing the trunk from raising, maintained for 6 seconds, and recorded by an electromyograph for further analysis. RMS *(Root Means Square) values were analyzed and* normalized by the MVIC (maximum voluntary Isometric Contraction).

The evaluations were made by a duly qualified researcher; and the application of the exercises, by another researcher qualified in PM.

Intervention

The exercise program occurred three times a week, lasting from 50 to 60 minutes per session, being performed a series of 10 repetitions for each exercise, with a total of 12 sessions.

Before the 12 sessions proposed, one session was held for familiarization with the Reformer apparatus, the exercises selected and the principles of the method.

The TG was initially submitted to a global muscle preparation session held on the ground through self-stretching, performed in three series, maintaining each one for 20 seconds.

Then, the volunteers were subjected to the PM exercises (Footwork toes, Leg series one leg (Figure 1), Hundred – variation, Arms up and down, Arms pulling and Bridge) carried out on the Reformer apparatus. The Hundred exercise, which originally should be repeated 100 times (10 series of 10 repetitions), was adapted, and a series of 10 repetitions was performed. This variation was used because the volunteers were beginners in the method and, also, to standardize the training volume in all exercises.

(A) (B)

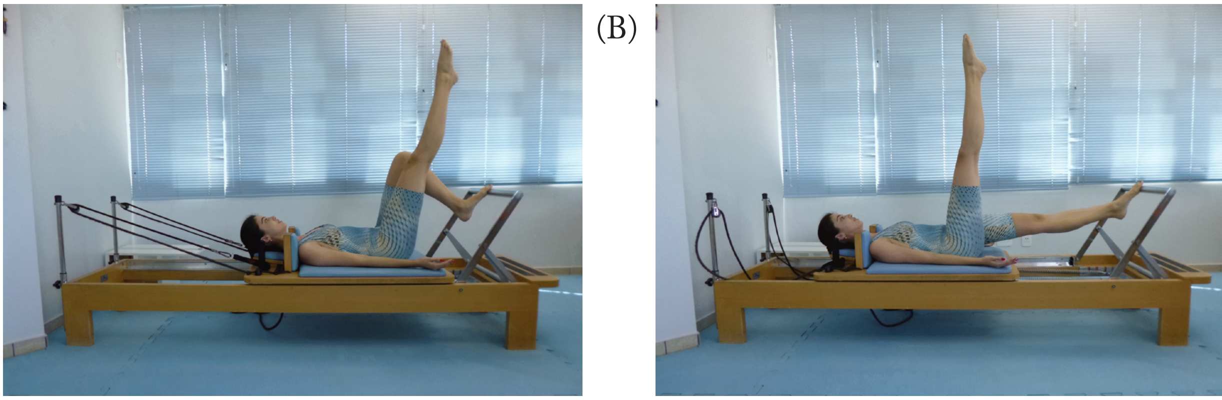

Figure 1. Application of the exercise Leg series one leg in the Reformer apparatus
A: initial position, B: final position.
Source: Author's personal archive.

For cooling down, at the end, respiratory exercises were performed in supine position on the ground. The CG did not participate in the training program with the PM exercises and did not practice another form of regular exercise in the period of the study.

Statistical analysis

In the statistical analysis, the data were analyzed by mean and standard deviation for each variable. The *Shapiro-Wilk* test was used for verifying data normality. The two-way analysis of variance (ANOVA) was used for comparisons between groups (TG and CG) and the moments (initial and final). For multiple comparisons, we used the post-hoc Scheffé test, to identify specific differences in the variables in which the values of F were higher than the statistical significance criterion set ($p<0.05$). To check the differences between age and BMI, between the groups, we used the paired t-test.

RESULTS

The groups Control and Trained were paired for age and BMI. The average age and the initial anthropometric data for both groups (CG and TG) are described in Table 1. No significant difference between the groups was observed for the variables analyzed.

Table 1. Initial values of anthropometry and of age of the groups (mean ± standard deviation)

Groups	Body mass (kg)	Height (m)	BMI (kg/m^2)	Age (years)
Control	66.0 ± 8.3	1.64 ± 0.04	24.5 ± 3.2	28.4 ± 4.1
Trained	63.4 ± 8.3	1.67 ± 0.05	22.7 ± 2.9	29.6 ± 4.0
p			0.1500	0.4919

p<0.05: significance value.

The values of MIP and MEP obtained and predicted are described in Table 2. The initial average of the values obtained was already above the average of the values predicted for the population analyzed. A statistically significant difference was observed ($p=0.039$) between the initial (116.6 ± 12.8) and final (120 ± 12.8) values of MIP in the Trained Group, as well as between the initial (75.3 ± 12.4) and final (89.3 ± 13.7) values of MEP in the same group ($p=0.0005$).

Table 2. Values of inspiratory and expiratory maximum pressures obtained (mean ± standard deviation)

Groups	MIP (cmH_2O)			MEP (cmH_2O)		
	Initial	Final	p	Initial	Final	p
Control	115.0 ± 13.8	115.8 ± 12.8	0.750	78.3 ± 20.6	79 ± 20.6	0.79
Trained	116.6 ± 12.8	120 ± 00.0	0.039*	75.3 ± 12.4	89.3 ± 13.7	0.0005*
p	0.65	0.12		0.52	0.34	

p<0.05: significance value.

Average of the values predicted for the population evaluated (cmH_2O): 95.9 for MIP and 97.5 for MEP.

The results of electromyography are described in Table 3. The average RMS values of each group and between groups were used, comparing the initial and final moment. A statistically significant difference ($p=0.03$) was observed between the initial (42.1 ± 14.3) and final (76.7 ± 28.1) moment of the TG for the left rectus abdominis muscle and tendency to significance was observed ($p=0.062$) for the right rectus abdominis muscle (initial moment: 39.1 ± 21, final moment: 73.3 ± 42.4).

Table 3. RMS values of abdominal rectus for the different groups (mean ± standard deviation)

Groups	Right rectus abdominis			Left rectus abdominis		
	Initial	Final	p	Initial	Final	p
Control	48.3 ± 18.9	55.8 ± 18.6	0.38	46.5 ± 20.9	57.8 ± 18.1	0.23
Trained	39,1 ± 21	73.3 ± 42.4)	0.062	42.1 ± 14.3	76.7 ± 28.1	0.03*
p	0.34	0.25		0.63	0.16	

* p<0.05: significance value.

DISCUSSION

This study examined the effect of 12 PM sessions using the Reformer apparatus on the respiratory muscle strength and the electrical activity of the rectus abdominis muscle. An increase in the MIP and MEP was observed, with a statistically significant difference in the electrical activity of the left rectus abdominal muscle, only after the program, partially confirming our hypothesis.

One of the tools used was the manovacuometer, which is simple, practical and precise in the assessment of respiratory muscle strength[15], and easy to handle, with possibility of adjustment[5] and with use in several studies[16-19].

Another tool was the electromyography, which provides results of great clinical interest, in addition to being a scientifically consecrated and accepted method[20]. In this study, the electromyographic analysis was performed after and before the exercise program, unlike other studies that made this analysis during the execution of Pilates-specific positions/exercises[21-23]. The evaluation method proposed aimed to verify the chance to gain a better abdominal muscle activation, as occurred in the TG, which would result in a gain in motor control.

The significant result in the right rectus abdominis muscle and not significant in the left side can be related to the evaluator's position at the time of the evaluation. In all the evaluations, he was positioned on the left side of the participants, in which the electromyography equipment and the computer monitor were also arranged. However, a tendency to significant values on the right side was observed, and maybe more sessions or participants would be required to show gain in muscle activation.

In this study, a program lasting 50 to 60 min daily was used, similar to that of other authors[18,24], and which occurs in most of the PM intervention studies[25]. The 12 sessions proposed comprise a short-term physical exercise program, which commonly occurs in the clinical practice – in the first four to eight weeks of exercises, neuromuscular adaptations are the main occurrence[26]. In the systematic review by Cadore et al.[27], who investigated neuromuscular adaptations resulting from resistance training in older adults, the improvement in the maximum muscle strength can be explained by neural and morphological adaptations. The main neural adaptations to resistance exercise are the increase in the motor unit recruitment and in the frequency of these units.

Some studies corroborate and others contradict our results regarding the MIP and MEP in the TG. Rafael et al.[28] assessed healthy youths in 10 ground Pilates sessions, and significant increase was achieved only for the MIP. Santos et al.[3] used a more extensive program, with 20 ground Pilates sessions, and detected increase in the MIP and MEP. This study obtained the same result, demonstrating that 12 sessions were enough to show respiratory muscle strength gain. However, there are studies that found different results, such as that by Jesus et al.[7], in which no significant difference in the values of MIP and MEP was verified in 24 sessions. One highlights that the studies found are aimed at ground PM, differing from this study, which used a specific apparatus, the *Reformer*, allowing working practically the entire body through the strengthening and stretching of the muscles[25]. This apparatus was chosen because of the diversity of physical exercises that can be performed on it and the ease of manual adjustments possible to adapt it to the particularities of each individual.

One believes that the positive results found in the TG of this study are primarily attributed to two principles that guide the PM: Breath and centering. The diaphragm muscle (the main inspiratory muscle) has free excursion during normal breath while the abdomen is relaxed because the abdominal muscles and internal organs provide little resistance to its movement. This dynamics changes during the PM exercises because, to perform the lateral breathing (typical breathing of the method), the diaphragm muscle builds up resistance in its excursion by contracting the abdominal muscles (principle of Centering, which promotes active contraction of muscles of the abdominal region throughout the exercise to promote the stability of the lumbar spine)[29], avoiding the displacement of organs by increasing the intra-abdominal pressure and the tension of the diaphragm muscle, which possibly causes its strengthening[3].

In the medical and sportive daily life, physical fitness and/or rehabilitation is known to occur in the short term. Thus, this study contributes to showing that, with fewer sessions, gains in respiratory muscle strength and in abdominal muscle activation are possible.

As the participants are young and healthy, the initial values of the MIP and MEP obtained were already above the values predicted for this population. A limitation of this study is the fact that individuals with a diagnosis of respiratory failure were not assessed. Initially, people considered to be healthy were chosen to outline the training program and the evaluation and, subsequently, to devise studies with specific populations.

Other limitations of this study were the small number of participants, the absence of sample calculation and the use of only one PM apparatus for performing the physical exercises proposed, once the routine of the method consists of performing exercises using diverse devices and ground exercises in the same session.

CONCLUSION

The 12 Pilates sessions using the Reformer apparatus improved the respiratory muscle performance, both increasing the inspiratory muscle strength (MIP) and the expiratory muscle strength (MEP) and promoting improvement in the rectus abdominal muscles in healthy women.

Although this study assesses healthy people, the results indicate that the PM may be an important resource for treating respiratory muscle failure. One suggested studies evaluating the effect of PM on individuals having some degree of impaired respiratory muscle can be conducted to highlight, as a complement, the PM benefits.

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