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The Morphological and Performance Response of Pilates Training in Active Women

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ABSTRACT

Cruz TMF, Rosa FO, Marchetti PH, Luna NMS, Fedele TA, Greve JMA, Rodrigues MB, Verlengia R, Lopes CR. The Morphological and Performance Response of Pilates Training in Active Women. **JEPonline** 2016;19(6):52-63. The purpose of this study was to investigate the muscle activation and fatigue post high volume Pilates training and the acute implications on the strength performance and morphological responses related to muscle tissue of lower limb**.** Twelve healthy young trained women performed one session of Pilates using a Wunda Chair. In two distinct moments (pre- and post-intervention), transverse relaxation time (T2)-weighted magnetic resonance (MR) images and isokinetic test evaluations of the lower limbs were recorded. There were significant increases in T2 signal intensity post-intervention for the gluteus maximus and throughout the muscle portion (proximal, medial, and distal) of the vastus lateralis and rectus femoris. There were significant decreases in performance from pre- to post-intervention in peak torque, total work, and average power of the extension moment. However, in the flexion moment, there were no significant differences in performance between pre- and post-intervention. The findings confirm that the Pilates method, when applied with the control of variables such as time series, repetitions, and rest intervals, promotes a modification of muscle strength and volume of the affected muscular groups. The ability to manipulate training variables when applied to Pilates apparatus promotes similar acute changes as reported in strength training studies.

Key Words: Exercise, Muscle Fatigue, Pilates Training, Physiology

INTRODUCTION

The Pilates method is currently being used as a training tool across a broad spectrum of clinical applications from rehabilitation, to improving physical capabilities specific to various sports, and even as a means to combat chronic inflammatory diseases (11,39). The increasing popularity of Pilates prompted an increase in research investigations to evaluate the influence on physical performance (8,21,27,31,32). The Pilates morphological changes and the training variables are not well defined. As a result, very little research has been conducted on how the different variables in Pilates training can be manipulated and combined to influence the given outcomes as muscle activation and fatigue (10). The few existing studies pertaining to Pilates and their changes have been conducted on previously sedentary individuals with no experience in the Pilates method (7,13,15,19,25).

Moreover, only a few have evaluated the morphological, fatigue effects and performance changes with Pilates practice, and yet most of them only mention the Mat Pilates (i.e., without apparatus) and include sedentary subjects and athletes (2,9,14,17,30). Regardless, the intensity and volume of training in the Pilates sessions range from 30 to 60 min with few repetitions, about 10 of each exercise, representing low mechanical work for the targeted muscle groups (28).

The Pilates apparatus load control employs the use of springs. Each spring has its own strength, given in kg / f, differing with each machine and according to the manufacturer. It is presumed that Pilates apparatus exercises would be better compared to Pilates mat exercises since there is better control of the training intensity, which is considered a key variable for inducing neuromuscular adaptations. Considering that the Pilates method is not designed to work with high volumes of training classes, it would be useful to verify whether the volume can produce fatigue, muscle activation, acute morphological and functional changes in physically active and experienced individuals. Until the present moment, there is no research about muscle activation of agonists and antagonists of lower limbs in Pilates method with volume and intensity higher than that used in practical daily classes.

Therefore, the main purpose of this study was to investigate the muscle activation and fatigue post high volume Pilates training and the acute implications on the strength performance and morphological responses related to muscle tissue of lower limb muscles in women.

METHODS

Subjects

Eligible participants were recruited and the final sample included 12 healthy young trained women (mean ± SD: 31.6 ± 5.4 yrs of age; body mass: 56.9 ± 5.1 kg; height: 161 ± 0.1 cm; Baecke score: 8.99). The subjects had an average 2 yrs of experience with Pilates method with at least 4 times·wk^{-1}. The subjects had no previous surgeries on the lower extremities and no history of injuries with residual symptoms (pain and/or "giving-away" sensations) in the lower limbs within the last year. This study was approved by the University research ethics committee, and all subjects read and signed an informed consent document (#80/12).

Experimental Approach to the Problem

Volunteers attended one session in the laboratory. Prior to data collection, the subjects were asked to identify their preferred leg for kicking a ball, which was then considered their dominant leg. Anthropometric data were measured, such as weight, height, and Baecke score (1). Weight was measured using a digital scale (Techline ®), height was measured using a stadiometer (Sanny®), a questionnaire was given about health status, injuries, physical activity level (Baecke score), and Magnetic Resonance Image (MRI) security questions to ensure the following of pre-assessment guidelines.

The baseline tests were MRI scan using a Magnetic Resonance (MR) scanner (General Electric GE, HDXT model, 1.5 Tesla) to evaluate transverse relaxation time (T2)-weighted of thigh muscles of dominant leg and isokinetic test using the Biodex Multi-Joint System 3 dynamometer (Biodex Medical TM, Shirley, NY, USA). The post-intervention tests includes MRI scan and isokinetic test. All procedures were supervised and measured by the same researcher using the dominant lower limb. Each subject was instructed to refrain from drinking alcohol or participating in any kind of training for 72 hrs before the MRI images were recorded.

Intervention

Pilates Method

The subjects performed one session following the Pilates method (PMA® apparatus Pilates exercises) using a Wunda Chair (Balanced Body™) for 30 min, focusing on the lower limbs. The session involved 8 exercises including: (1) double leg pumps (heels); (2) double leg pumps (toes); (3) double leg pumps (V position); (4) single leg pumps (heels); (5) single leg pumps (toes); (6) standing leg pump; (7) isometric lunge with flexion; and (8) extension of the back leg PMA® study guide exercises (22). All subjects performed a total of 24 sets and 720 repetitions (Table 1), and the duration of each repetition ranged from approximately 20 to 40 sec (concentric and eccentric phases of the movement). The rest interval between sets and exercises was adjusted to 30 sec. All subjects were verbally encouraged and motivated to make maximum efforts during the exercises.

Table 1. Pilates Exercises and Protocol.

Pilates Exercises	Sets	Repetitions	Rest Interval (sec)
1. **Double leg pumps** (heels)	3	30	30
2. **Double leg pumps** (toes)	3	30	30
3. **Double leg pumps** (v position)	3	30	30
4. **Single leg pumps** (heels)	3	30	30
5. **Single leg pumps** (toes)	3	30	30
6. **Standing leg pumps**	3	30	30
7. **Isometric lunge with flexion**	3	30	30
8. **Isometric lunge with extension**	3	30	30

Procedures

MRI Evaluation

Before and immediately after the Pilates exercises, T2-weighted MR images of the dominant and non-dominant thigh muscles were obtained with an MR scanner (General Electric GE, HDXT model, 1.5 Tesla). The subjects were placed in the magnetic bore (8-CH HD Body Full coupled to an MRI system) in a comfortable and relaxed supine position (distal-proximal direction). Tocoferoll marks on the surface of the quadriceps femoris, adductor magnus, and biceps femoris muscles aligned with the crosshairs of the scanner, which allowed for similar positioning for repeated scans. Imaging procedures were identical for the resting scans and the scans after exercise. The image sequence had the following parameters: T2 map (FOV 38; width/spacing of cut 8.0 mm/1.0 mm; matrix 256 x 256; 1.0 NEX; TR 1750; TE Multi - 8.0; BDW 41; 24 cuts); axial STIR (FOV 38; width/spacing of cut 8.0 mm/1.0 mm; matrix 256 × 320; 2.0 NEX; TR 4525; TE17; BW 31); axial T1 (FOV 38; width/spacing of cut 8.0 mm/1.0 mm; matrix 352 x 256; 2.0 NEX; TR 767; TE minimum; BW 41; 24 slices); and coronal T1 (FOV 48; width/spacing of cut 5.0 mm/1.0 mm; matrix 384 x 256; 1.0 NEX; TR 667; TE min; BDW 62; 24 cuts). The average time from completion of the exercise to initiation of the scanning was 75 ± 17 sec. The length of the right femur, taken as the distance from the intercondylar notch of the femur to the superior boundary of the femoral head, was measured in the coronal plane. Subsequently, a total of 30 axial scans were obtained from 4 cm to 45 cm from the hip joint for location of the proximal, medial, and distal portions of the gluteus maximus muscles, biceps femoris (long head), vastus lateralis, and rectus femoris. Non-contractile tissues, such as blood vessels and fat tissue, were excluded. The total time of this evaluation was around 18 to 20 min.

Isokinetic Test

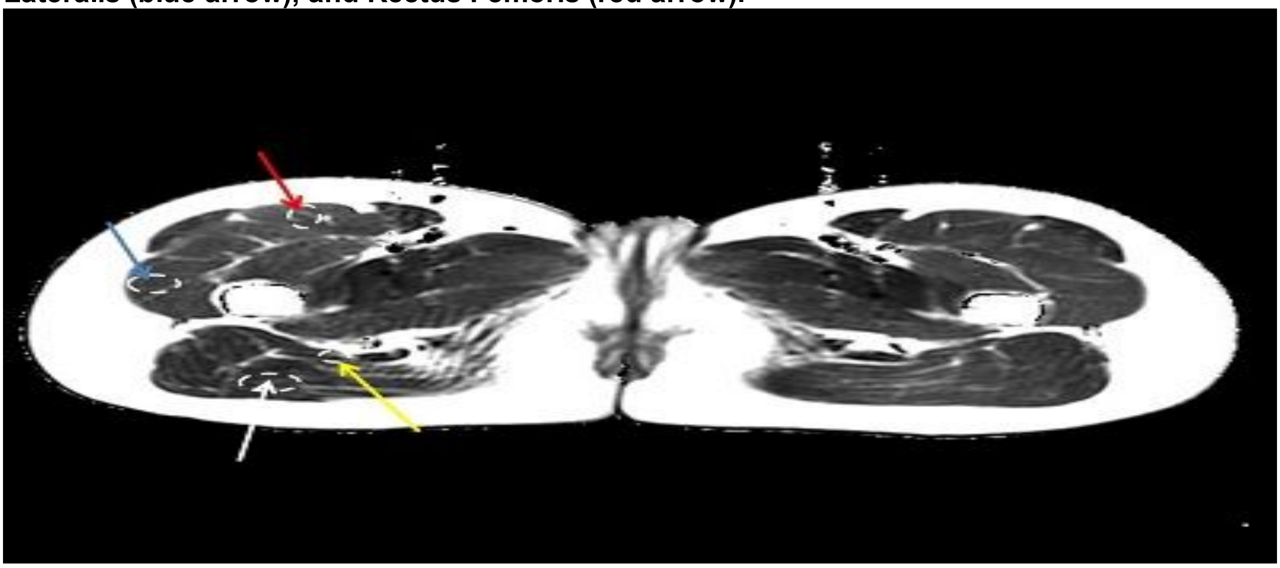
A knee extension–flexion (concentric–concentric) isokinetic evaluation was performed in a Biodex Multi-Joint System 3 dynamometer (Biodex Medical TM, Shirley, NY, USA). The tests were performed in both legs. First, in the dominant leg and then in the non-dominant leg. After a standardized warm-up (cycle-ergometer for 5 min without load) subjects were positioned in the equipment according to the manufacturer's instructions (seated with arms against the body, hands holding the lateral handles, and strap stabilization of trunk, hip, and tested thigh). The gravitational correction was performed at 40° of knee flexion. The isokinetic test at $60°\cdot sec^{-1}$ concentric/concentric was used for data collection. Five maximal repetitions were performed twice (Test 1 and Test 2), and a 60-sec rest period was used between Test 1 and 2 for all subjects. Consistent verbal commands were given during the tests. All tests were conducted by the same researcher.

Data Analyses

MRI Analyses

All images were analyzed using Image J software (Java-based version of the public domain NIH Image Software; Research Services Branch, National Institutes of Health) A T2 value (in mm2) was determined for each voxel, on the image, using the MRI analysis calculator plugin. Next, the regions of interest (ROI) were defined on the T2 images of each portion proximal (Figure 1), medial, and distal of the following muscles: gluteus maximus, biceps femoris (long head), vastus lateralis, and rectus femoris. The average signal intensity in T2 mm2 was calculated, and its mean value was computed for each selected slice of the proximal, medial, and distal portions of the selected muscles. A total of 30 images from 4 cm to 45 cm from the hip joint were analyzed. All variables were evaluated in both moments (baseline- and post-intervention).

Figure 1. Muscle Proximal Portion: Regions of Interest (ROI) Proximal Portion of the Following muscles: Gluteus Maximus (white arrow), Biceps Femoris Long Head (yellow arrow), Vastus Lateralis (blue arrow), and Rectus Femoris (red arrow).



Isokinetic Analyses

The peak torque (PTQ), adjusted for body weight (PTQ/BW), total work (TW), and average power (AP) were evaluated at baseline and post-intervention.

Statistical Analyses

The sample size calculation was based on a pilot study with 2 women, considering the variable peak torque adjusted for body weight. To determine the sample size required to compare two means, nine subjects were necessary to achieve an alpha level of 0.05 and a power (1-β) of 0.80.The normality and homogeneity of variances within the data were confirmed with the Shapiro–Wilk and Levene tests, respectively. To compare the differences between moments (pre- and post-intervention) a Student *t* test was used for the dependent variables from the MRI and isokinetic tests. A repeated-measures ANOVA (2x3) (moment x muscle section) was used to measure the differences.

RESULTS

There were significant increases in T2 signal intensity post-intervention for the gluteus maximus, and throughout the muscle portion (proximal, medial, and distal) of the vastus lateralis and rectus femoris muscles. There were no significant differences in the results for the biceps femoris muscle (long head) (Table 2). There were significant decreases in performance pre- and post-intervention in PTQ, TW, and AP for the extension moment. But, in the flexion moment, there were no significant differences in performance (Table 3).

Table 2: MRI T2 Intensity Signal-Pre and Post–Intervention.

Muscle	Section (mm2)	Pre (Mean ± SD)	Pos (Mean ± SD)	P
Rectus Femoris	Proximal	36.4 ± 2.3	44.9 ± 4.2	<0.001*
	Medial	34.8 ± 1.2	44.7 ± 2.8	<0.001*
	Distal	35.2 ± 1.0	45.8 ± 2.5	<0.001*
Vastus Lateralis	Proximal	39.4 ± 3.0	50.8 ± 5.1	<0.001*
	Medial	37.6 ± 2.4	50.2 ± 5.7	<0.001*
	Distal	38.7 ± 2.2	49.4 ± 4.2	<0.001*
Biceps Femoris (LH)	Proximal	37.7 ± 2.4	45.5 ± 6.9	>0.05
	Medial	35.5 ± 1.8	36.0 ± 2.7	>0.05
	Distal	36.0 ± 1.8	35.5 ± 2.0	>0.05
Gluteus Maximus	Proximal	40.9 ± 2.9	45.9 ± 5.6	0.02*

SD: standard deviation *P≤0.05

Table 3. Isokinetic Evaluation in Extension and Flexion Moments pre- and Post-Intervention.

Extension	Pre (Mean ± SD)	Post (Mean ± SD)	P
Peak Torque (N•m)	128.9 ± 24.6	107 ± 23.4	<0.001*
Total Work (W)	469.9 ± 78.5	379 ± 66.7	0.002*
Average Power (J)	85.6 ± 17	71.9 ± 17.6	0.008*
Flexion			
Peak Torque (N•m)	63.8 ± 14.6	65.8 ± 15.1	0.27
Total Work (W)	252.3 ± 61.9	258.2 ± 61	0.532
Average Power (J)	45.2 ± 11.9	48 ± 12.8	0.21

SD = standard deviation, *P≤0.05

DISCUSSION

The aim of this study was to investigate the use of training variables, as volume, intensity, pause, and load in fatigue and its morphological changes in physically active women. The main finding was that Pilates exercises with apparatus was efficient to promote morphological changes, muscle activation, and fatigue of the target muscles. It is difficult to find similar results to the present study. Until now, this is one of the first studies to investigate muscle activation, fatigue, and the training variables (volume, intensity, and rest) in physically active women. Previous studies have demonstrated that Pilates training promotes improvements in the physical fitness of young athletes (4,13,19) and yet, one study does not confirm this hypothesis (25). It is difficult to compare these studies because of the differences in manipulation of training variables (i.e., intensity, volume), Pilates training methods (mat exercises vs. apparatus), evaluations types, and sedentary subjects.

The muscle morphological changes are one of the most readily studied factors in conjunction with exercises in the literature. For characterizing muscle performance are peak power and intensity of T2 signal (6). The development of acute fatigue is accompanied by decreases in peak power and increases in T2. The fatigue mechanism depends on factors such as the protocol type and the training variables: total time, volume, intensity, and rest pause. The increase in T2 signal is also related to exercise intensity (16,37) and the number of repetitions of exercise performed with a given load. The T2 changes have been attributed to a redistribution of water molecules in the muscle cells (similar to a swelling phenomenon post-injury) (23).

Many studies have demonstrated that the fundamental properties of MRIs can be used to visualize muscle damage. The training variables such as volume and intensity are important in acute and chronic responses of resistance training. Our findings confirm that the Pilates method, when applied with the correct selection of exercises and training variables in only one session of 30 min, promotes significant morphological and functional adaptation during the fatigue and muscle activation of the targeted muscular groups. It is important to remember that the training variables, such as volume and intensity might influence the adaptive response and increase sports performance. The neural and muscular adaptations related with improvements in power and muscle strength occur predominantly in type II muscle fibers (12,23). Therefore, considering that the Pilates method is not a high-intensity exercise (low number of maximum repetitions), the stimulus and adaptations for muscle fiber recruitment of high threshold fibers (type II) was achieved with our protocol. Studies with healthy subjects reported that Pilates training significantly improves flexibility (20,26-28), abdominal muscle strength (5,18), and muscular endurance. However, the subjects submitted to Pilates training were sedentary and non-experienced with Pilates method.

The results showed an increase in T2 signal intensity in all the thigh muscles immediately after Pilates apparatus training, corresponding to the increase in metabolic muscle activity, except for the biceps femoris (long head). Wakahara et al. (38) studied a different type of training and muscle groups, but also used MRI and T2 signal. Our data corroborate those of Wakahara et al. (38), who concluded that the triceps regional differences related to muscle hypertrophy after chronic force training can be attributed to the same regional differences in muscle activation obtained during an acute exercise session.

The long head of the biceps femoris muscle is considered to be the prime mover of hip extension and external rotation knee accessory. Both portions (long head and short head) act at the knee joint. In this case, the specificity of the movements used in our protocol, with few repetitions in hip extension and knee flexion movements, may have contributed to the low activation. These results are in accordance with Mendeguchia et al. (25), who found positive responses with increased T2 signal immediately after the practice of Nordic walking in the biceps femoris (short head), semitendinosus, and semimembranosus. However, as in the present study, the biceps femoris (long head) did not have a significantly changed T2 signal even though there was muscle activation throughout the muscle fiber (proximal, medial, and distal) of the anterior chain muscles (rectus femoris and vastus lateralis). In the posterior chain, only the gluteus maximus was significantly changed. The biceps femoris muscle showed no significant increase in T2-intensity signal. Moreover, there were no changes in muscle strength, which was likely due to the selection of exercises that prioritized the action of the knee extensor muscles.

Our study evaluated only the regional differences in muscle activation in an acute training session with Pilates. It is believed, according to the literature review, that chronic training using this same protocol could cause muscle hypertrophy at the same muscle regions as shown in the study by Wakahara et al. (38). Other studies, such as Dorado et al. (12) and Hides et al. (18) also showed increases in T2 signal in the abdominal and lumbar multifidus after Pilates practice in a chronic training protocol >10 wks.

In the present study, the subjects' performance decreased in the PTQ, AP, and TW variables, corroborating the findings of Sesto and colleagues (33) and Paschalis et al. (27). Though these research studies examined different populations and muscle types, they also found a drop in the subjects' performance. It seems that the selection of exercises is essential to change muscle performance and balance. For example, despite the fact that the double leg pump exercise uses the flexor muscles, it was not enough to cause a change in the condition of the long head of the biceps femoris muscle.

As noted in this study, there were significant acute decreases in PTQ, TW, and AP and significant increases in the intensity of the T2 MRI signal that suggest acute muscle fatigue of the knee extensor muscle chain in relation to muscle strength performance parameters. Similar data with the Pilates method have not been found in the literature to date. Most of the studies that examined training variables and their adaptations are related to strength training (3,5,20). It is already know in the literature that acute fatigue and acute muscle activation in chronic training is capable of promoting muscle strength and hypertrophy. The acute morphological and functional changes demonstrated in the present study seem to be very similar to those with strength training and hypertrophy (24,25,27,33,36,38). Thus, the use of high intensity and volume training in the Pilates method appears to be effective in promoting beneficial adaptations, including the improvement in muscle strength and hypertrophy.

Researchs about Pilates training only investigate the usual volume of a Pilates apparatus class, reaching the maximum of 60 repetitions per class, the present study used a protocol of 270 repetitions with perceived maximum effort during the execution of movements, resulting in a performance drop and significant muscle activation that can lead to adaptations related to improvement muscular strength.

The innovation of this study is to demonstrate that a greater volume and intensity can be considered for use in Pilates classes, and that the exercises used in the proposed session were effective in muscle activation and consequent fatigue. The training variables (volume, intensity, speed of execution, rest intervals, loads, etc.) throughout training are important in promoting morphological, physiological, and biomechanical adaptations (7,10,13,15,19,25, 38). Therefore, it is apparent that every method used to improve physical fitness should be monitored for its effectiveness (34,35,36).

CONCLUSION

The Pilates method has been indicated by health professionals for regular people, the aging, and athletes to improve and promote muscle strength, flexibility, coordination, balance, etc. However, to achieve these benefits, the modification of mechanical environment through the training variables is imperative.

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