Ultrasound Evaluation of the Abdominal Wall and Lumbar Multifidus Muscles in Participants Who Practice Pilates: A 1-year Follow-up Case Series

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Abstract

Objective: The purpose of this study was to describe ultrasound (US) changes in muscle thickness produced during automatic activation of the transversus abdominis (TrAb), internal oblique (IO), external oblique (EO), and rectus abdominis (RA), as well as the cross-sectional area (CSA) of the lumbar multifidus (LM), after 1 year of Pilates practice.
Methods: A 1-year follow-up case series study with a convenience sample of 17 participants was performed. Indeed, TrAb, IO, EO, and RA thickness, as well as LM CSA changes during automatic tests were measured by US scanning before and after 1 year of Pilates practice twice per week. Furthermore, quality of life changes using the 36-Item Short Form Health Survey and US measurement comparisons of participants who practiced exercises other than Pilates were described.
Results: Statistically significant changes were observed for the RA muscle thickness reduction during the active straight leg raise test ($P = .007$). Participants who practiced other exercises presented a larger LM CSA and IO thickness, which was statistically significant ($P < .05$). Statistically significant changes were not observed for the domains of the analyzed 36-Item Short Form Health Survey ($P > .05$). A direct moderate correlation was observed ($r = 0.562$, $P = .019$) between the TrAb thickness before and after a 1-year follow-up.
Conclusions: Long-term Pilates practice may reduce the RA thickness automatic activation during active straight leg raise. Furthermore, LM CSA and IO thickness increases were observed in participants who practice other exercise types in conjunction with Pilates. Despite a moderate positive correlation observed for TrAb thickness, the quality of life did not seem to be modified after long-term Pilates practice. (J Manipulative Physiol Ther 2018;41:434-444)
Key Indexing Terms: *Abdominal Muscles; Exercise Movement Techniques; Paraspinal Muscles; Ultrasonography*

Introduction

The Pilates method, created by Joseph Pilates, is based on the coordination of body, mind, and spirit and promotes the uniform development of the body by restoring good posture and physical activity.[1] It aims to strengthen the core muscles through more than 500 strengthening and stretching exercises. The Pilates method may be divided into 2 modalities: mat and machine. The exercises with machines are carried out with resistance applied by springs and pulleys.[2] There is general agreement about the anatomic delimitation of the core or powerhouse, which runs from the bottom of the pelvic floor to the top of the rib cage. This would be the central point of the Pilates method, and based on a good control of the same, it also includes the participation of the rest of the limbs in the exercises.[3]

It is a very popular training method in the field of rehabilitation and well-being, and its principles are similar to the training of the stability of the spine through motor control. The resistance and activity of the abdominal and lumbar muscles recently have been considered the best option to improve the stability of the spine.[4]

Although there is no universally accepted definition for core stability, and different studies assess the transversus abdominis (TrAb) and lumbar multifidus (LM) muscles as

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primary stabilizers, others point out that no specific core element is more important than another for lumbar stability, all of which contribute to the optimal lumbopelvic stability required for sports practice and functional activities.[3,5] Therefore, more and more studies verify the muscular activation of the stabilizing muscles of the spine, mainly the TrAb and internal oblique (IO) muscles, with ultrasound (US) images through the practice of Pilates exercises.[6-9]

The muscular activity of the LM has not been measured with US in Pilates studies; however, its activity has been shown with surface electromyography (EMG) data in some Pilates exercises.[10-13]

The muscles of the abdominal wall, such as rectus abdominis (RA) in the midline, and laterally the external oblique (EO), IO, and TrAb work in a coordinated way with the diaphragm, LM, and pelvic floor muscles for control of the spine under normal circumstances.[14] In the case of lumbopelvic pain, functional deficits of the muscles of the abdominal wall have been found.[15,16]

Quality of life is another important factor that is present in studies that value the effects of Pilates in participants who practice it. The 36-Item Short Form Health Survey (SF-36) is one of the most widely used and evaluated health-related quality of life instruments. It is a generic scale that provides a profile of health status, includes items of physical function and physical role, and is considered in conjunction with the new versions of an instrument very suitable for use in research and clinical practice.[17] Different Pilates studies have used this questionnaire to assess the effect of training with the Pilates method on quality of life, showing an improvement in almost all subscales in older adults,[18] in all subscales in median adult age,[19] and functional capacity, pain, and vitality subscales in adults with chronic low back pain.[20]

The use of US in the practice of physiotherapy to assess muscle morphology and to guide rehabilitation decision making has increased quickly during the last decade as a reliable and valid option to be used in clinical practice.[21] The use of US imaging in the field of neuromusculoskeletal rehabilitation has been called rehabilitative US imaging (RUSI) and defined as "the procedure used by physiotherapists to assess muscles and soft tissue morphology and their function during physical exercise and is used to assist in the application of therapeutic interventions aimed at improving neuromuscular function."[22] Its purpose is to improve our understanding of the relationship between motor control and function, to determine which patients can benefit from the therapeutic approach of treatment through specific exercises, to increase documentation on the effect, to improve the effectiveness of treatments, and to increase feedback.[21] After the international symposium of RUSI in May 2006, RUSI has been applied in the clinic and in research to study the abdominal wall muscles and the back.[23,24]

In 2009, a systematic review aimed to determine whether RUSI was a valid measure of trunk muscle size and activation and whether such measures were sensitive to change compared US with magnetic resonance imaging and EMG; results suggested that the change in thickness in these muscles was a valid measure of the activity of these muscles at moderate levels of effort and that RUSI was sensitive to both positive and negative changes.[25] Different cross-sectional studies have used RUSI to measure and compare the thickness and recruitment differences of these muscles in healthy participants and in those with low back pain.[26,27]

Indeed, more and more physiotherapy clinics offer Pilates therapeutic classes as a training method that improves the health of the locomotive system, prevents pain, and promotes the general well-being of the people who perform it. Also, the use of therapeutic US by physiotherapists to evaluate muscle morphology and muscular function in people with musculoskeletal problems is growing and is a valid and practical method to assess the evolution of certain pathologies or conditions.[21,22,25] Quantification, within the limits of the study, of the changes in muscle contraction that are observed after a year of performing Pilates is useful information for the patients who practice it, for those who want to do it, and for the physiotherapy therapeutic objectives that arise when using the Pilates method in the long term.

The found studies evaluated the muscular activity of the abdominal wall and the multifidus by Pilates exercises in the short term.[6-13] To the authors' knowledge, no studies with a 1-year follow-up observed the change in muscle contractions at their request through automatic activation tests in people who performed Pilates. The study would be a first approach to assess longitudinally, with a 1-year follow-up, changes in abdominal wall muscle thickness and cross-sectional area (CSA) during contraction of main lumbar-stabilizing muscles. It cannot be determined that the effect is directly due to Pilates because there is no control group or random assignment, but it serves as an approximation for future observational studies and clinical trials.

Therefore, the primary aim of this study was to describe the changes in muscle thickness that occur during the activation of the TrAb, IO, EO, RA, and CSA of the LM, as measured with US, in the sample of participants performing Pilates for 1 year by using automatic activation test. Furthermore, the secondary purposes of this research were to describe (1) the observable differences (or lack thereof) between the effects of Pilates and those of other sports, including changes in muscle thickness; (2) the changes in the quality of life of participants in the sample who performed Pilates during 1 year, as measured by the SF-36; and (3) the correlations among the muscular activity of the different valued muscles.

Methods

Study Design

A 1-year follow-up case series study with a convenience sample of 17 participants was carried out between March 2016 and April 2017. A flow chart of the participants through

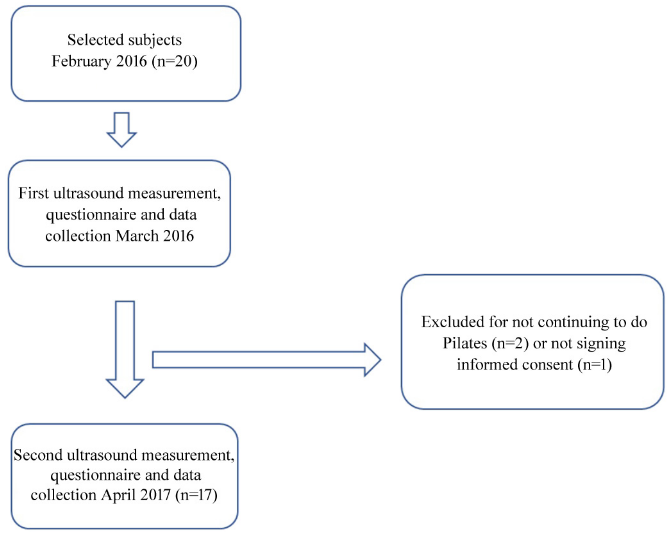

Fig 1. *Flow diagram of the passage of the participants in the study.*

the phases of the study may be observed in Figure 1. The recommended Consensus-based Clinical Case Reporting Guideline Development criteria have been followed.

Sample

We included 17 participants who performed Pilates at the CARMASALUD Clinical and Research Center in Madrid, Spain. Indeed, a convenience sample of 20 participants was selected in February 2016, but 3 were excluded for the second measurement after 1 year.

The inclusion criteria were age between 30 and 65 years and performing Pilates on a mat, machines, or mixed 2 days per week at the CARMASALUD Clinical and Research Center. The exclusion criteria were having a body mass index (BMI) greater than 31 kg/m^2, lumbar pain, congenital abnormalities, pregnancy, neurological signs or surgeries, cognitive alterations, and a score on the Nijmegen Questionnaire >24 that would determine respiratory dysfunction.[26]

Ethical Statement

The study was approved by the Research Committee of the Complutense University of Madrid and by the ethics committee of the San Carlos Hospital of Madrid (approval code: 17/105-E_TFM). All participants in the study signed the informed consent form.

Sociodemographic Data

The collected sociodemographic data were age (year), sex (male/female), BMI (kg/m^2) as a function of weight (kg) and height (m), profession, other sports practice (yes/no), and the time participants were carrying out Pilates before the first US measurement (months).

Main Outcome Measurements

The main outcome measurements of the study were the differences in the CSA of the L4-L5 LM muscle and thickness of the TrAb, IO, EO, and RA muscles between the US measurement in muscle contraction by automatic activation test and the basal measurement of each analyzed muscle, which was measured in cm for thicknesses and cm^2 for the CSA. For the evaluation of the abdominal muscles, the active straight leg raise (ASLR) automatic test was used, and the participant was asked to lift the stretched homolateral leg (at the measurement site) in the supine position without any further verbal order. For the LM muscles, the contralateral arm lift test was used at the measurement site, requesting the participant to elevate the contralateral arm.[23] This measure was summarized with the mean and standard deviation (SD) of the sample and will be compared by repeating the same measures 1 year later to analyze the changes observed in the same sample with statistical tests.

Secondary Outcome Measurements

Furthermore, the changes in the quality of life measured with different subscales of the SF-36 (from 0 to 100) by comparing the results of March 2016 with those of April 2017. The general quality of life of the participants was assessed using the Spanish version of the SF-36, which consists of 36 questions divided into 8 subscales covering physical function, physical role, body pain, general health, vitality, social function, emotional role, and mental health. In addition, the SF-36 includes transition item that asks about the change in the general health status with respect to the previous year. This item is not used for the calculation of any of the scales but provides useful information about the perceived change in health status during the year preceding the administration of the questionnaire. The score

Fig 2. *Ultrasound image of the TrAb, OI, and OE muscles.* OE, *external oblique;* OI, *internal oblique;* TrAb, *transversus abdominis.*

ranges from 0 to 100, with the highest scores denoting a higher quality of life. The subscales of physical function, physical role, general health, and vitality were used.[17]

Procedure

To control the sample during the year of follow-up, class absences and changes in the frequency of Pilates performance during that year were counted, as well as whether they had performed or perform another sport besides Pilates. In order to describe the sample at baseline, the time that these patients were performing Pilates before the first US measurement was also recorded. The variables of the sample measured in March 2016 were collected, and the same variables were collected again 1 year later, adding the variables of absences from Pilates classes and participation in other sports during that year.

The collection of information, delivery of informed consent, and measurement of variables (US, anamnesis, and completion of the SF-36) were performed in an individual interview with each participant of the sample at the CARMASALUD Clinical and Research Center. Participants were previously advised to confirm that they wanted to participate in the study. Three participants were excluded: 2 did not continue to practice Pilates in the same center, and 1 did not want to participate. Therefore, the final sample was 17 participants.

US Measurements Protocol

A high-quality US diagnostic system was used (Philips Ultrasound, Bothell, Washington) using a 4- to 9-MHz curvilinear transducer (Philips C9-4 Convex Ultrasound Transducer). The principal investigator of the study performed the US assessment by assigning a numerical code to each participant, placing the probe, and recording the images (basal and muscle thickness using the relevant test). Subsequently, another physiotherapist with expertise in RUSI performed the calculation of the thicknesses and relevant CSA blindly because the participants were identified only by the code.

Measurements were performed on the right side. The probe was curvilinear. The images were always performed at the end of a normal expiration. A total of 24 images were carried out per patient (IO, EO, TrAb, RA, and L4-L5 LM).

TrAb, IO, and EO Muscles. Participants were placed in a supine position, with the homolateral arm under the head and with the knees and hips slightly flexed (placing a loop under the knees). The transducer was placed in the anterolateral area of the abdominal wall, superior to the iliac crest and perpendicular to the midaxillary line, remaining perpendicular to the skin. The image was taken at the end of a normal expiration, when the muscles were relaxed. A total of 6 pictures were carried out for baseline measurement (3 with both lower limbs supported) and for the automatic activation by the ASLR test (3 with the lower homolateral leg elevated in hip flexion and knee extension). The participant was instructed to raise the stretched leg.[23,26] The US image can be seen in Figure 2.

RA Muscle. Participants were placed in a supine position with the homolateral arm under the head and with the knees and hips slightly flexed (placing a loop under the knees). The transducer was placed immediately above the navel and lateral to the midline (lateral to the navel) so that the cross-section of the muscle was centered in the image. The image was performed at the end of the exhalation, when the muscles were relaxed. A total of 6 images were carried out for baseline measurement (3 with both lower limbs supported) and for the automatic activation by means of the ASLR test (3 with the lower homolateral leg elevated in

Fig 3. *Ultrasound image of the RA muscle.* RA, *rectus anterior.*

Fig 4. *Ultrasound image of the L4-L5 MF.* MF, *lumbar multifidus.*

hip flexion and knee extension). The participant was instructed to raise the stretched leg.[23,26] The US image may be seen in Figure 3.

LM Muscles. Participants were placed in prone position. The transducer was placed first transverse to the spinous processes of L4-L5 (L4 is located drawing a straight line from the iliac crest to the lumbar area). The transducer was placed longitudinally and laterally to the spinous processes, so that the zygapophysial joints of L4-L5 were placed in the center of the image. Images were taken at the end of expiration. A total of 6 pictures were performed (6 with transducer in transverse position) for basal measurement (3 with both arms relaxed) and for the measurement in muscle activation by means of the contralateral arm lift test (3 with the contralateral arm elevated). Participants were asked to raise the straight arm.[23] The US image can be seen in Figure 4.

Statistical Analysis

Statistical Package for Social Sciences, version 15.0 for Windows (SPSS Inc, Chicago, Illinois), was used for data

Table 1. *Summary of the Sociodemographic Data of the Sample*

Sociodemographic Data	N	Minimum	Maximum	Mean	SD
Age (y)	17	30	63	47.58	8.35
Weight (kg)	17	47	89	64.17	11.65
Height (m)	17	1.56	1.82	1.66	0.08

SD, standard deviation.

Table 2. *Difference of Means Between 2016 and 2017 of the Main US Outcomes by Automatic Activation Test (ASLR and CAL), Obtained by Student* t *Tests of Related Samples*

Mean Variable 2016-2017	Muscle	Difference	SD	95% CI	*P* value
Thickness (cm, ASLR)	TrAb	-0.0228	0.09	(-0.069 to 0.023)	.311
Thickness (cm, ASLR)	IO	-0.066	0.23	(-0.188 to 0.056)	.269
Thickness (cm, ASLR)	EO	-0.046	0.12	(-0.109 to 0.017)	.147
Thickness (cm, ASLR)	RA	0.0797	0.1	(0.025 to 0.134)	.007
CSA (cm^2) CAL	LM	0.1698	2.45	(-1.094 to 1.433)	.779

ASLR, active straight leg raise; *CAL*, contralateral arm lift; *CI*, confidence interval; *CSA*, cross-sectional area; *EO*, external oblique; *IO*, internal oblique; *LM*, lumbar multifidus; *RA*, rectus abdominis; *SD*, standard deviation; *TrAb*, transversus abdominis; *US*, ultrasound.

analysis. An α error of 0.05 (95% confidence interval) and a desired power of 80% (β error of 0.2) were used for all statistical tests. Regarding the descriptive statistics, the quantitative variables were expressed as the mean ± SD, except for the variable months that were carried out by Pilates prior to the first US measurement, which was expressed with the median and interquartile range (IR).

A normal distribution was assumed with respect to the main study variable for the use of parametric tests, because it was an anatomic variable in healthy participants, with the inclusion and exclusion criteria pertinent. The trend of distribution was visually analyzed using histograms. Ultrasound measurements were grouped with the mean as a measure of position and the SD as a scatter measure to compare before and after 1 year.

The Wilcoxon test was used for 2 related samples without assuming normality of the variable score in the different subscales to detect changes in the quality of life pre- and post-1 year, after visual analysis of the distribution of the variable. A *P* value of <.05 with a 95% confidence interval was considered statistically significant.

The association between the different measurements of the main variable (continuous quantitative variables) was analyzed using the Pearson correlation coefficient as a function of the covariance.

For the assessment of the differences in thickness and CSA between participants who performed a sport other than Pilates and those who did not, the results were presented using box-plots to compare the variability within and between groups, and the Student *t* test for 2 independent samples (those who performed Pilates and those who did not) was used to assess whether there were significant differences.

Results

Sociodemographic Data

The summary of relevant sociodemographic data corresponding to the first measurement of variables in 2016 is shown in Table 1. The mean ± SD of BMI was 23.17 ± 2.99 kg/m^2. Very similar values in the second measurement were recorded, varying only in the mean weight ± SD to 63.88 ± 10.91 kg. The total study population (17 participants) included 4 men and 13 women. Of the 17 participants, 6 practiced another sport (or more than 1) throughout the year. The other 11 participants only practiced Pilates. The 17 participants had been practicing Pilates before the first measurement for a time median ± IR of 3 ± 5 months (range 1-6 months) and the IR was 5 months.

US Outcome Measurements

Regarding the comparison of means of the main variable in 2016 and 2017, there are no significant differences (P > .05), so we cannot affirm that there were significant changes of muscular thicknesses in the automatic muscular activation after 1 year. Only significant differences were detected in the RA muscle (P < .05), with a decrease in muscle thickness during the activation test after 1 year occurred. All data are presented in Table 2.

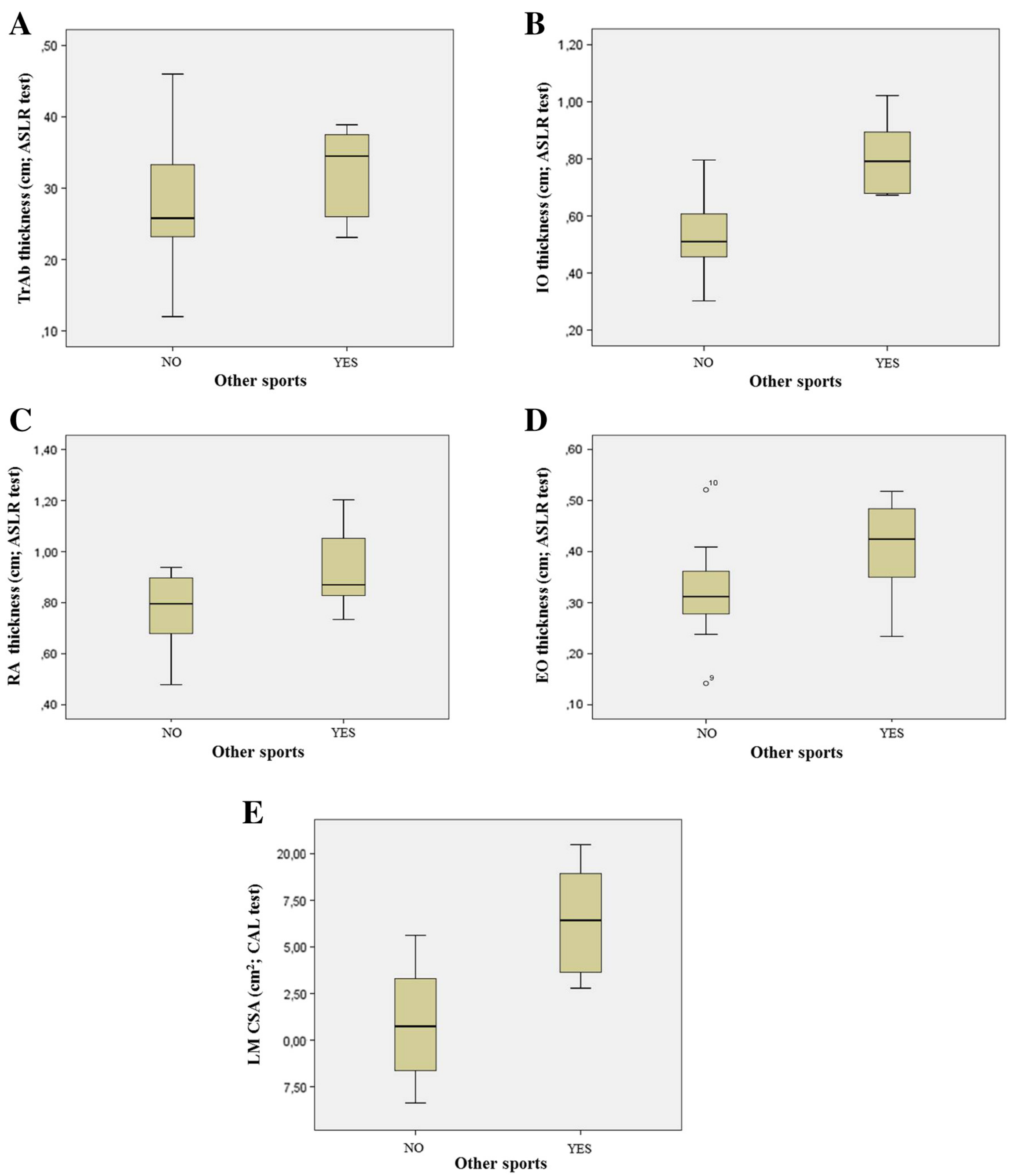

Fig 5. *Box-plots to illustrate the differences in the second measurement (2017), between participants who perform other sports and those who only perform Pilates, for the thickness (cm) of the TrAb (A), IO (B), RA (C), and EO (D) during ASLR test and the CSA (cm^2) of the LM (E) muscle during CAL test.* ASLR, *active straight leg raise;* CAL, *contralateral arm lift;* CSA, *cross-sectional area;* EO, *external oblique;* IO, *internal oblique;* LM, *lumbar multifidus;* RA, *rectus abdominis;* TrAb, *transversus abdominis.*

Of the 17 study participants, 6 practiced another sport during the year of follow-up compared with 11 who only performed Pilates. We observed differences in the second measurement (2017) between groups: participants who performed other sports and those who only performed Pilates; these can be observed in the different box-plots of Figure 5 (A, B, C, D, and E).

We assessed whether these differences were significant by performing the Student *t* test for independent samples, assuming Levene's test equal variances (P > .05), and concluded that the observed differences were significant (P = .001) in the LM by finding the difference between the basal measurement and automatic activation (main outcome), which was 3.87 cm^2 in the group that performed another

Table 3. *Mean Differences Between Participants Who Perform Another Sport and Those Who Only Perform Pilates (2017) of the Main US Outcome Measurements by Automatic Activation Test (ASLR and CAL) Obtained by Student* t *Tests of Independent Samples*

Main US Outcomes (2017)	Muscle	Other Sports Mean ± SD (n = 6)	Pilates Mean ± SD (n = 11)	*P* value
Thickness (cm, ASLR)	TrAb	0.06 ± 0.06	0.08 ± 0.11	.69
Thickness (cm, ASLR)	IO	0.11 ± 0.23	0.078 ± 0.15	.701
Thickness (cm, ASLR)	EO	-0.0018 ± 0.08	0.04 ± 0.09	.31
Thickness (cm, ASLR)	RA	0.003 ± 0.07	0.006 ± 0.10	.96
CSA (cm^2, CAL)	LM	3.87 ± 1.09	1.29 ± 1.31	.001

ASLR, active straight leg raise; *CAL*, contralateral arm lift; *CSA*, cross-sectional area; *EO*, external oblique; *IO*, internal oblique; *LM*, lumbar multifidus; *RA*, rectus abdominis; *SD*, standard deviation; *TrAb*, transversus abdominis; *US*, ultrasound.

Table 4. *Mean Differences Between Participants Who Perform Another Sport and Those Who Only Perform Pilates (2017) of the Main US Outcome Measurements in Contraction by Automatic Activation Test (ASLR and CAL) Obtained by Student* t *Tests of Independent Samples*

Main US Measurements in Muscle Contraction (2017)	Muscle	Other Sports Mean ± SD (n = 6)	Pilates Mean ± SD (n = 11)	*P* value
Thickness (cm, ASLR)	TrAb	0.324 ± 0.06	0.277 ± 0.10	.337
Thickness (cm, ASLR)	IO	0.808 ± 0.13	0.533 ± 0.15	.002
Thickness (cm, ASLR)	EO	0.405 ± 0.10	0.32 ± 0.09	.113
Thickness (cm, ASLR)	RA	0.926 ± 0.17	0.765 ± 1.16	.072
CSA (cm^2, CAL)	LM	16.45 ± 3.02	10.801 ± 3.08	.002

ASLR, active straight leg raise; *CAL*, contralateral arm lift; *CSA*, cross-sectional area; *EO*, external oblique; *IO*, internal oblique; *LM*, lumbar multifidus; *RA*, rectus abdominis; *SD*, standard deviation; *TrAb*, transversus abdominis; *US*, ultrasound.

sport and 1.29 cm^2 in the group of Pilates only. Also significant were the differences in the automatic activation of the IO muscle thickness of participants performing another sport (0.808 cm) compared with those who only practiced Pilates (0.533 cm) and in the CSA of the LM muscle of the participants who performed other sports (16.45 cm^2) compared with those who only performed Pilates (10.80 cm^2); both measures had a value of $P = .002$. Results are presented in Tables 3 and 4.

Quality of Life

There were no significant differences ($P > .05$) for the scores of physical function ($P = .317$), physical role ($P = .317$), general health ($P = .057$), and vitality ($P = .932$) for each subscale of the SF-36 assessed after 1 year of performing Pilates.

Correlation Analysis

Analyzing the correlations between the different quantitative outcome measurements, a moderate correlation ($R = 0.562$; $P = .019$) was found between the main US outcome measurement (difference in automatic and baseline activation) for the TrAb thickness in 2016 compared to that of 2017.

Discussion

This is the first Pilates study with US measurements that analyzes changes in muscle thickness and CSA with follow-up of 1 year. According to the results obtained, the hypothesis presented at the beginning of the study is not fully confirmed, because no significant differences were observed in the muscular thickness of all abdominal muscles and the CSA of the LM after 1 year of performing Pilates 2 days per week. It is important to note that the muscular measurements were obtained by automatic activation tests, with the variable being the difference between activation and baseline measurements (cm for the abdominal wall and cm^2 for the LM muscles). However, the significant difference (decrease) in RA muscle thickness assessed by the ASLR test is interesting because it could be related to a decrease in RA activity and an increase in the stability of the lumbar region. This decrease in activity of the abdominal surface musculature, such as the RA muscle, has already been studied with EMG.[28] Although the use of US is a valid and less invasive measure of detecting changes in muscle morphology, which in turn is related to muscle activity and can be used to infer muscle activity,[29] there are many factors that can influence muscle activity, and the relationship among activity, strength production, and muscular rigidity in many cases is still unclear.[30] It is therefore necessary to continue investigating the relationship between EMG and RUSI.

Pilates studies with US measurements similar to the present study have not been found to compare data on changes in muscle thickness and CSA assessed using automatic activation tests. Previous studies focused on the muscle activity of TrAb, IO, and EO during Pilates exercises, and despite all being pre-post studies, the follow-up was not 1 year. Endleman and Critchley,[6] who assessed the muscle thickness of TrAb and IO at rest compared with well and poorly done Pilates exercises, provided the first evidence that a selection of classic Pilates exercises activates TrAb and IO. They observed significant increases in thickness compared with resting position and a moderate correlation (R = 0.410, P = .01) between TrAb and IO thickness. Because they sought to find differences in muscle thickness just between rest and Pilates exercises, and not as a pre-post study to 1 year, their results are not comparable with those of the present study. Their results, however, suggest support of our initial hypothesis, because if the TrAb and IO are activated in Pilates exercises, changes in the muscular thickness should occur after 1 year of regular training.

Moon et al[7] compared the superficial muscle activity measured with EMG (EO and RA) and the deep muscle thickness (TrAb and IO) measured with US scanning during rest and performing 4 column stability exercises in 3 groups: experts in Pilates (n = 10), instructors of resistance exercises (n = 10), and a control group (n = 10) of sedentary people. It was concluded that Pilates and resistance exercises were effective in improving deep abdominal muscle thickness. No significant differences were found among groups in muscle activity of RA measured with EMG. One of the stability exercises was the 1-leg raise, which can be compared with the ASLR used in this study.

One of the objectives of a previous uncontrolled clinical trial[8] was to verify the effect of a Pilates training program on the muscular thickness of the abdominal wall muscles on a convenience sample that included 16 sedentary women, measured before and after 8 weeks of Pilates training. The thickness of the TrAb, IO, and EO was measured with US in rest position (supine position at the end of the expiration), with results showing an increase in thickness of the same (significant differences P < .05). However, the study population is not comparable because the sample of the present study was not sedentary women.[8]

Another pilot study[9] employed 2 groups of participants with no Pilates experience: 1 group performed Pilates and the other stretched, with 2 lessons per week for 8 weeks of training. The muscle thickness of TrAb and IO was measured during 3 exercises: imprint or pelvic scale, Hundred A and Hundred B (2 types of abdominal exercises), and functional postures (sitting and standing). The results did not indicate muscle thickness changes in the resting or functional postures, and the authors concluded that Pilates training increased the activity of the TrAb but only when performing the Pilates exercises, which seems to coincide with the results of the present study. More research is needed on how to increase deep abdominal muscle activity during functional activities.[9]

To our knowledge, no previous Pilates studies have evaluated the RA and LM muscles with US. Interesting results have been obtained regarding the LM muscle, with significant differences in muscular thickness in the participants of the sample who performed sports other than Pilates. This suggests that it is a variable that must be considered for future studies.

Pilates teachers at the clinic where the study was performed were physiotherapists and collegiate experts in motor control, and classes did not exceed 4 students, so supervision of the correct performance of the exercises was assumed. Perhaps no significant differences were found in US measurements because the automatic activation tests used were not as sensitive to changes in muscle thickness as the specific Pilates exercises that stabilize the abdomen and lumbar spine. Because this was a retrospective study, the same measurement protocol had to be followed 1 year before, continuing the same line of research. However, we could have controlled for the participants' experience level with Pilates before the first measurement so that the sample was more homogeneous and included participants with the same level of training.

Previous studies have demonstrated the effectiveness of Pilates in improving the quality of life as measured with the SF-36, obtaining significant differences in the subscales in older adults compared with a control group that did not perform Pilates.[18] A 12-week Pilates workout in sedentary middle-aged people significantly improved all physical and emotional components of the SF-36 in one study,[19] and another study showed significant improvement in the subscales of functional capacity, pain, and vitality in people with nonspecific lumbar pain compared with a control group that did not perform Pilates.[20] In the present study, no significant differences were detected, although there was a tendency for improvement in the subscales. Significant differences may not have been detected because our sample included healthy, non-sedentary people without lumbar pain; other possible reasons include the lack of a control group and the size of the sample.

Difficulties and Limitations of the Study

Because it was a retrospective study without a control group and with a convenience sample, there was a selection bias, and we cannot establish cause–effect relationships. Therefore, it is not possible to extrapolate the results of the sample to the study population. More studies are needed with a control group and a larger sample size to determine the effect of Pilates on the abdominal muscle thickness and CSA of the long-term LM. All patients in the sample missed between 1 and 2 months of Pilates classes between July and September of the year between measurements (2016).

Practical Applications

- Long-term Pilates practice may decrease the automatic activation of the RA muscle.
- Other forms of exercise types may alter the LM or IO muscle contraction.
- The automatic muscle activation causes and effects of Pilates and other exercise types should be studied in the long term.

Conclusions

Long-term Pilates practice may reduce the RA thickness automatic activation during ASLR. Furthermore, LM CSA and IO thickness increases were observed in participants who practiced other exercise types in conjunction with Pilates. Despite a moderately positive correlation observed for TrAb thickness, the quality of life did not seem to be modified after long-term Pilates practice.

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Contributorship Information

Concept development (provided idea for the research): P.G.-A., C.C.-L., A.G.-M., G.P.-M.
Design (planned the methods to generate the results): P.G.-A., C.C.-L., A.G.-M., G.P.-M.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): P.G.-A., C.C.-L., G.P.-M.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): P.G.-A., A.S.-I., A.G.-M.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): P.G.-A., C.C.-L., G.P.-M.
Literature search (performed the literature search): P.G.-A., C.C.-L., A.S.-I., P.M.-C., G.P.-M.
Writing (responsible for writing a substantive part of the manuscript): P.G.-A., C.C.-L., G.P.-M.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): P.G.-A., C.C.-L., A.S.-I., A.G.-M., P.M.-C., G.P.-M.

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