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ORIGINAL ARTICLE

Effectiveness of adding voluntary pelvic floor muscle contraction to a Pilates exercise program: an assessor-masked randomized controlled trial

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Abstract
Introduction and hypothesis The purpose of this study was to evaluate the effectiveness of adding voluntary pelvic floor muscle contraction (PFMC) to a Pilates exercise program in sedentary nulliparous women.
Methods Fifty-seven healthy nulliparous and physically inactive women were randomized to a Pilates exercise program (PEP) with or without PFMC. Forty-eight women concluded this study (24 participants for each group). Each woman was evaluated before and after the PEP, by a physiotherapist and an urogynecologist (UG). Neither of the professionals was revealed to them. This physiotherapist measured their pelvic floor muscle strength by using both a perineometer (Peritron) and vaginal palpation (Oxford Scale). The UG, who performed 3D perineal ultrasound examinations, collected their data and evaluated the results for pubovisceral muscle thickness and the levator hiatus area (LA). Both professionals were blinded to the group allocation. The protocol for both groups consisted of 24 bi-weekly 1-h individual sessions of Pilates exercises, developed by another physiotherapist who specializes in PFM rehabilitation and the Pilates technique.
Results The PEP+ PFMC group showed significantly greater strength improvements than the PEP group when comparing the Oxford scale, vaginal pressure and pubovisceral muscle thickness during contraction measurements at baseline and post-treatment.
Conclusions Our findings suggest that adding a voluntary PFMC to a Pilates exercise program is more effective than Pilates alone in improving PFM strength in sedentary nulliparous women.

Keywords Pilates exercises · Pelvic floor muscle contraction

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Introduction

The Pilates technique was invented by Joseph Pilates and incorporates of a series of low-impact exercises that produce strength and flexibility in the entire body [1].

While practicing Pilates exercises, it is fundamental to adopt a standardized breathing technique, with the purpose of facilitating performance of the exercises [2]. This technique consists of inhaling through the nose and exhaling through the mouth, while taking deep breaths. It helps to activate deep stabilizer muscles, especially the transverse abdominal muscle in conjunction with the pelvic floor. This synchronized movement improves stabilization of the pelvis and trunk [3].

As muscle contraction of the pelvic floor occurs during most of these exercises, many instructors believe that Pilates exercises can significantly improve pelvic floor strength. Further studies are required to determine if Pilates can actually have an influence on pelvic floor muscle (PFM) strength [4].

Modern Pilates exercise programs incorporate exercises that involve breathing and pelvic floor muscle contraction (PFMC). These muscles are not specifically, but are incidentally trained, during exercise and movement [5].

Training is a well-established treatment for PFM dysfunctions. It has been demonstrated that, regular strength training stiffens the pelvic floor and provides structural support [6, 7].

The muscles have several functions. They surround the pelvic opening; during a voluntary contraction, these muscles constrict the urethra and increase urethral closure pressure, lift the pelvic organs inside the pelvis, stabilize and prevent descent during increased intra-abdominal pressure, and constrict the levator hiatus [8].

Three-dimensional (3D) ultrasound has been used to generate simultaneous sagittal, axial, and coronal views to provide more detailed information regarding the pelvic floor anatomy [9]. Perineal or translabial ultrasound is useful in determining bladder neck mobility and it helps in assessing pelvic organ prolapse, levator function, and puborectalis muscle [10].

Vaginal palpation is often used to evaluate muscle strength and teach patients how to perform a correct contraction of the PFM [11]. Several vaginal palpation rating scales have been used in clinical practice [12]. As a result, moderate correlation has been between the digital evaluation of PFM strength using readings of maximum squeeze pressure obtained with a manometer and the Oxford Grading Scale [13]. Therefore, the aim of this study was to evaluate the effectiveness of adding voluntary PFMC to a Pilates exercise program in sedentary nulliparous women.

Materials and methods

Study design

Fifty-seven healthy nulliparous and physically inactive women were enrolled in this assessor-blinded, randomized, controlled trial at the Division of Urogynecology and Reconstructive Pelvic Surgery, Federal University of São Paulo, Brazil.

The study was approved by the Review Board Committee of this institution (CEP 1855/10) and was registered at ClinicalTrials.gov (NCT02748473). Each participant provided written informed consent.

Inclusion criteria were healthy women (without any gynecological/neurological disease), women who were sedentary (do not practice physical activities regularly) nulliparous, of reproductive age, with no history of pelvic floor disorders, and capable of performing correct PFMC. Women were not included if they were not able to perform a correct PFMC. Potential subjects were excluded if they had chronic degenerative diseases affecting muscular and nerve tissues, diabetes, cerebrovascular disease or overt neurological conditions, pregnancy, autoimmune connective tissue disorders or had previously undergone pelvic floor re-education programs and/or pelvic floor surgery.

The volunteers were recruited via invitations that had been put in two elevators at the commercial building where the Pilates studio is located. The invitations clarified the aim of the study, inclusion criteria, and included the telephone number of the main researcher of this study. When contacted by telephone, the researcher explained the study, informed the potential participant about the available time schedule for the Pilates exercise sessions, in addition to the location of the outpatients department where the initial and final evaluations were taking place.

Based on preliminary measurements of PFM strength via perineometry, a prospective sample size calculation called for 23 patients in each group to have 80 % power for detecting a 20 % difference in muscle strength between groups.

Although the minimum number of patients required was 23 for each group, we recruited more volunteers to increase the sample size in case of any drop-outs.

The main investigators were masked to the study groups and not involved in the interventions.

Considering the inclusion criteria, a sealed envelope system for randomization was used to divide the 57 volunteers into two groups. Two sealed envelopes were identical (same size, same texture, and were opaque). We mixed the two envelopes before the volunteers entered the room. These envelopes, each containing the words “Pilates exercises program” and “ Pilates exercises with PFM contraction” respectively, were presented to the volunteers (individually). The subject had to choose one of them.

Group I Pilates exercise program (PEP), involving only the Pilates exercises protocol without any instruction of a voluntary PFM contraction. In other words, the researcher had never, under any circumstances, explained anything about a voluntary PFMC during the Pilates exercise performance.

Group II Pilates exercises program with voluntary pelvic floor muscle contraction (PEP + PFMC) composed of a Pilates exercises program with voluntary pelvic floor contractions. This included maximum contraction of the pelvic floor muscles during expiration with five repetitions alternately, thus avoiding any muscle exhaustion to the pelvic floor.

After being randomized, all volunteers were presented to the Gynecology Ambulatory of the Federal University of São Paulo, where their initial evaluation with a physiotherapist, specialized in pelvic floor rehabilitation, would take place. This professional did not have knowledge of the randomized results, and conducted the evaluation by first filling an individual file on each volunteer with their data and anamnesis (file content of personal data, such as age, address, phone, profession, height, and weight). Once the file was completed, the physiotherapist measured their PFM function and examined their ability to contract it. However, all outcome measures were not presented to this professional, to prevent the final results from being influenced.

Testing the PFM contraction

Instructions were given concerning anatomy and function of the PFM by using drawings. The training began with diaphragmatic breathing, followed by the patients being instructed to contract the PFM during exhaling. A mirror was used to visualize the muscle contractions in many positions. The physiotherapist observed if the exercise was being correctly performed in a cranio-ventral direction, which led to an upward movement of the levator plate during the PFMC [14]. The participants were requested to "lift and squeeze the PFM as hard as possible". Patients who were able to perform the correct contraction were referred for assessment of muscle strength.

Pelvic floor muscle strength

The evaluation of the strength was determined by assessing the vaginal squeeze pressure using a Peritron™ (Cardio Design™, Oakleigh, VIC, Australia), and the Oxford scale. The participants were instructed to urinate before the examination. To evaluate the vaginal squeeze pressure (cmH_2O), a vaginal balloon catheter was used (balloon size diameter 26 mm x length 108 mm) with an active surface measurement length of 33 mm. The maximal voluntary contraction (MVC) reading was recorded after the catheter was inflated to 100 cmH_2O (3.5 cm inside the vagina [15]). Three consecutive MVCs were recorded (cmH_2O), with a 10-s interval between efforts.

The physiotherapist advised the patient to "lift and squeeze the PFM as hard as possible". Co-contraction of the gluteal muscles, hip adductor or rectus abdominal muscles was discouraged through previous instruction. To ensure valid measurement during the examination, visible contraction of these muscles was not allowed. Owing to the anatomical relationship, the co-contraction of the tranversus abdominus was naturally accepted. Only contractions with simultaneous observable inward movement of the perineum were considered valid. The mean of three maximal voluntary contractions were calculated. This method has been found to be reliable and valid if used with the simultaneous observation of an inward movement of the catheter and perineum during PFM contraction [14].

For each contraction, the peak pressure and the mean pressure were measured. The peak pressure was considered the maximum value of each contraction and the mean pressure was considered the mean value of each contraction.

Each volunteer did three contractions and for each contraction, one measure of peak pressure and mean pressure were measured. To obtain the final result, an arithmetic mean of the three observations was recorded.

The PFM contraction was also assessed by digital examination, using the five-point Oxford Grading Scale [16].

The order of the evaluation was randomized by using two sealed envelopes. These were identical (same size, same texture, and were opaque). We mixed the two envelopes before the volunteers entered the room. These envelopes, containing in each the words "Oxford Scale" and "Perineometry" respectively, were presented to the volunteers (individually) and the subjects had to choose one of these.

Ultrasound evaluation

The ultrasound evaluation was recorded in the same week and at the same outpatient visit as mentioned before. It measured the pubovisceral muscle thickness and the levator hiatus area (LA). The ultrasound equipment used was a GE Voluson 730 Expert systems with RAB 8-4 MHz volume transducers and an 85° acquisition angle. The examination was performed with the patient in the supine position with hip flexed and slightly abducted, after voiding. The US transducer was placed on the perineum in the midsagittal position, followed by a verbal request to contract the PFM, using the words "contract your PFM, as hard as you can, as if you need to urinate and cannot". By scanning, two images were recorded during rest and maximum voluntary contraction respectively. To capture this last image, the patient only needs to contract for approximately 3 s, which is the time needed for the equipment to carry out the scan.

The analysis of the images was conducted off-line, on a laptop by one professional, the urogynecologist. The thickness of the pubovisceral muscle was measured by 4D rendering image software processing a 3D image, via a linear plot perpendicular to the direction of the muscular fiber, which started measuring from the external to the internal parts (the 7 o'clock direction in the circumference formed by the genital hiatus). Additionally, the genital hiatus area was also measured by the same software, but by drawing a circumference from the pubic symphysis, passing the linear face of the pubis, ischium, and the pubovisceral muscle, from one side to another, returning to the pubic symphysis (Fig. 1).

The evaluation process was performed by one blinded urogynecologist who had carried out the ultrasound examinations, before and after a 24-session Pilates program.

Is it important to highlight that women were evaluated both before and after a 24-session Pilates program.

Intervention: Pilates exercise program

The Pilates exercise program was carried out by another physiotherapist, specialized in PFM rehabilitation and the Pilates technique.

The protocol of both groups consisted of 24 bi-weekly 1-h individual sessions of Pilates.

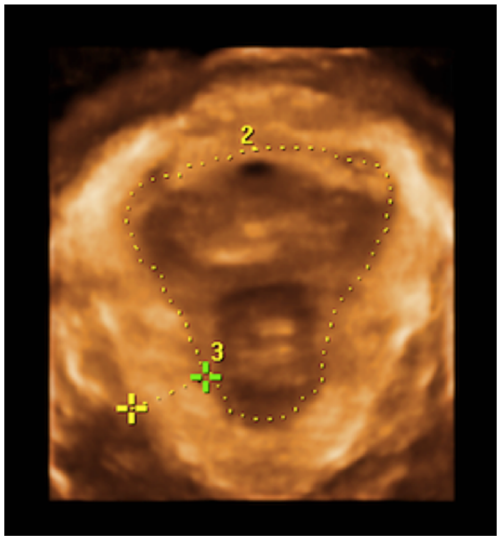

Fig. 1 Levator hiatus (*2*) and pubovisceral muscle thickness (*3*)

The first two sessions included instructions about the Pilates technique, breathing, transversus abdominis, muscle contraction, and all basic principles of the Pilates technique.

The following 10 sessions included basic exercises of the Pilates technique. The last 12 sessions included intermediate exercises. Each session was composed of 20 exercises: 4 exercises of Mat Pilates and four exercises on each of these pieces of equipment: Pilates Chair, Cadillac, Reformer, and Ladder Barrel. All participants did 4 exercises on each piece of equipment, with 10 repetitions each. The detailed description of the exercises is shown in Table 1.

Both groups performed the same protocol and a forced exhalation was requested during the practice of the Pilates technique to activate the transversus abdominis muscle. For the group PEP + PFMC the instructor asked for the maximum contraction of the PFM, during expirations with five repetitions performed alternately, thus avoiding PFM exhaustion.

After the 24 sessions, all participants in the two groups were retested with the same methods as the baseline.

Statistical analysis

Data analysis was performed by another professional who was blinded to the group allocation and had no knowledge of the interpretation of the results. The SPSS program (Statistical Package for Social Sciences, IBM, Chicago, IL, USA) was used for the statistical analyses.

Background variables were reported as frequencies or means with standard deviation (SD). To analyze the Oxford variable, the Mann–Whitney *U* test was used, whereas Student's *t* test was used to test baseline characteristics for other variables. The aim of this statistical analyses was determine if chances in one group were better than chances in the other group after treatment. Thus, the null hypothesis was that the means are equal whereas the alternative hypothesis consisted of the analysis of the mean of differences of the PEP + PFMC group being superior to the PE group. First, the F test was applied to verify the variances between groups, followed by the Student's *t* test for independent samples with equal and different variances. *p* values of <0.05 indicated statistical significance.

Results

Fifty-seven nulliparous and physically inactive women were recruited to the trial from May 2011 to May 2015. All of these women were able to perform a pelvic muscle contraction correctly, and no screened patients were excluded from the baseline. There was a differential dropout rate between groups.

Fifty-seven women with a mean age of 27.98 years (SD ± 5.43) were randomized into either the PEP ($n = 28$) or PEP+ PFMC ($n = 29$) groups (Table 2). At baseline, there were no significant differences between groups in terms of age, body mass index, ethnicity and education. When studying both groups separately, the average age of the PEP group was 27.41 years (SD ± 4.8) while the other group presented an average age of 27.98 years (SD ± 5.4). Additionally, the homogeneity test presented a *p* of 0.3173, which is not a significant result. Therefore, both groups are homogeneous about age .When analyzing the body mass index means, the PEP group had 23.60 kg/cm^2 (SD ± 3.1) while the PEP+ PFMC group had 23.01 kg/cm^2 (SD ± 2.8). Moreover, this homogeneity test was not considered significant, resulting on a *p* of 0.1853, which also confirmed the groups homogeneity about body mass index means. In terms of ethnicity, the PEP group presented of 85.7 % was Caucasian whereas the other group had 82.8 %. The homogeneity between the groups was confirmed with a *p* of 0.760. In terms of education, the PEP group presented 60.7 % finished the bachelor's degree whereas the other group presented 69.0 % finished the bachelor's degree. The homogeneity between the groups was confirmed with a *p* of 0.514.

Five participants dropped out of the PEP + PFMC group stating that they lived very far from the Pilates studio, and another left because she moved to another city. Two participants exited the PEP group as they disliked Pilates exercises and 2 more left the group as they did not have time to do the exercise session twice a week. The flowchart (Fig. 2) presents details of enrollment and fulfillment of the study protocol. Distribution of the patients based on demographic characteristics, ethnicity, and education before and after the treatment is shown in Table 3.

According to the information presented in Table 3, after some of the participants dropped out, the new mean age for the PEP group was 26.96 years (SD ± 4.8) whereas the PEP +

Table 1 Pilates exercise program

Week	Exercises	Description
1–2	Pilates breathing (mat)	Inhale slowly and deeply focusing on diaphragm movement and exhale "wringing" the breath out
1–2	1–2 neutral pelvis (mat)	Lie on back, knees bent, feet flat on mat
1–2	Knee folds (mat)	Lie on back, knees bent, feet off mat, arms are extended out to the side, rotate the pelvis to the left, use abdominals to bring the pelvis back to neutral and alternate slides
1–2	Heel slides (mat)	Lie on back, knees bent, feet on mat, extend leg out by pushing heel out along floor, alternate, then do both heels at the same time
1–2	Elevator (mat)	Sit upright, pelvis neutral, zip and hollow. Deep inhalation and exhale, repeat successively more deeply to lengthen spine
1–2	Pelvic clock (mat)	Neutral pelvis, imagine clock face on pelvis facing toward ceiling. Elevate pelvis so that 6 o'clock is higher and the lower pelvis so that 12 o'clock is higher
1–2	Pelvic rocks (mat)	Lie on back, knees bent, neutral pelvis then tilt from side to side
1–2	Coccyx curls (mat)	Lie on back, knees bent in neutral position. Draw navel in toward spine
1–2	Abdominal stabilization (mat)	Contraction of the abdominal muscle, pull navel back in toward spine
3–12	Rolling like a ball (mat)	On back, knees toward chest, feet off mat, hands behind thighs, chin to chest, roll back and then forward back to a balanced position
3–12	Rolls down (mat)	Stand, feet hip–distance apart, arms to hang loosely at sides, gently drop chin toward chest, roll forward slowly, roll back up, to regain original posture
3–12	Prep hundred (mat)	Lie on back, knees bent in table position, arms straight up then bring down to the sides. Inhale arms up and exhale arms down
3–12	Modified bridge (mat)	Lie on back with knees bent and feet in parallel. Press feet down into the floor to engage the hamstrings, lift the pelvis up toward the ceiling and one leg simultaneously
3–12	Hundred (reformer)	Lie on back, knees bent in table position, arms straight up, then bring down to the sides. Inhale arms up and exhale arms down
3–12	Foot work (reformer)	Neutral pelvis, feet on foot bar, heels together, and push out carriage. Keep abdominals engaged and incorporating breathing
3–12	Single leg (reformer)	Neutral pelvis, one foot on foot bar and one knees bent in table position and push out carriage
3–12	Leg circles (reformer)	Lie on back, knees bent, straighten one leg toward ceiling, then circular motion across body first with foot in foot straps.
3–12	Foot work (chair)	Seat on the chair, two feet in the pedal, knees bent, legs parallel, pump the pedal up and down
3–12	Single leg (chair)	Seat on the chair, one foot in the pedal with knee bent, straighten other leg and pump the pedal up and down
3–12	Hamstring press hips down (chair)	Lie on back on the floor, legs parallel and knees bent, both feet on the pedal, pump the pedal down and up
3–12	Adductor press (chair)	Lie on the side on the floor, one leg on the pedal, the other on the mat. Pump the pedal down
3–12	Ballet stretches (barrel)	Standing in front of the barrel with back toward the stairs, with an extended foot on the floor and the other leg on top of the barrel, lengthen spine
3–12	Side bends (barrel)	Standing seating, feet against the ladder and hip against the barrel. Arms holding the bat above the head. Lengthen the spine away from the ladder
3–12	Straight back (barrel)	Sitting in an upright position, knees bent on table position, arms straight and hands on the bat, lean torso back
3–12	Twist (barrel)	

Table 1 (continued)

Week	Exercises	Description
		Sitting in an upright position, legs and knees adducted at the same level on the hips, arms extended, and rotate the column
3–12	Breathing (Cadillac)	Lie on back, both legs on trapeze bar and both hands on the bar. Lift the hips and bend the elbows
3–12	Push through on back with back extension (Cadillac)	Lie on back, head toward the push bar, bend knees, feet on the floor, and pull the bar in toward the torso and straighten the legs and elbow
3–12	Airplane prep (Cadillac)	Lie on back, head toward the scroll bar, the vertical bar holding hands on the vertical bar, knees bent over the scroll bar, take a knee on the table position
3–12	Lateral press (Cadillac)	Standing, facing the scroll bar, arms stretched forward, press the bar down
13–24	Roller over (mat)	Lie on back, double knee fold one at a time with stability, connect inner thighs and softly point feet. Straighten both legs directly above torso until they are parallel with the mat
13–24	Double leg stretch (mat)	Lie on back, knees bent in table position, lengthen arms forward and place hands onto the outside of shins. Straighten both legs, pressing them away from torso on a low diagonal, simultaneously circle the arms out to the side and around to return back to the shins and draw the legs back in to the starting position
13–24	Double straight leg raises (mat)	Lie on back, knees bent in table position, keeping the elbows open and positioned just in front of ears, wheel neck and upper body off the mat, simultaneously straighten legs
13–24	Hundred (mat)	Lie on back, knees bent in table position, simultaneously straighten and slightly lower legs and beat the arms up and down.
13–24	Arms pulling straps (reformer)	Prone position on the box, head toward the pulleys, trunk and head out to the edge of the box, hands holding the ropes, pull arms down and back to push the carriage
13–24	Feet pulling straps (reformer)	Lie on back on the box, head toward the foot bar, legs and knees off the end of the box. Handle heels. Pull heels toward the gluteus to pull the carriage
13–24	Long stretch (reformer)	Hands on foot bar and feet on the shoulder support. Straight legs and arms. Bend shoulders to push the carriage
13–24	Front splits (reformer)	Forward position. One knee bent one the foot bar and straighten other leg put the foot on shoulder support. Straighten the knee to push the carriage
13–24	Frog lying flat (chair)	Lie on back on the mat, head away from the chair, bend knees and legs with lateral rotation. Push the pedal down
13–24	Hamstring press hips up (chair)	Lie on back on the mat, head away from the chair, legs parallel and abducted, feet on the pedals. Lift hips and thoracic spine to push the pedal down
13–24	Forwards step up (chair)	Standing in front of the chair, straighten one leg and put the foot on the pedals, ankle plantar flexion leg. Bend the other knee and put the foot on the chair, bringing the weight to the leg of the chair
13–24	Triceps press standing (chair)	Standing on the chair, hands on the top of the handles, bearing the weight of the body. Metatarsals in the foot, bend elbows while the body falls, push the pedal down
13–24	Lower and lift (barrel)	Prone position, head toward the barrel. Legs extended, adducted. Lower and raise legs
13–24	Leg circle (barrel)	Prone position, head toward the barrel, straight legs and make circular movements with both legs
13–24	Scissors (barrel)	Prone position, head toward the barrel, take one leg up high and the other down simultaneously
13–24	Beats (barrel)	

Table 1 (continued)

Week	Exercises	Description
		Prone position, head toward the barrel, straight legs and lateral rotation, ankle plantar flexion, inhale for 4 s, plantar flexion of the ankles and legs adduced at each inspiration, opening them slightly to "beat" together four times.
13–24	Twist with pulses (Cadillac)	Sitting, one hand on the center roll bar and the other under the roll bar, extended and parallel legs, rotate the column
13–24	Airplane (Cadillac)	Lie on back, with head toward the scrollbar, knees bent in table position and above the bearing, hands on the bar, bend hips to bring the bar toward the trunk
13–24	Teaser series (Cadillac)	Lie on back, head toward the push bar. Hands on the bar, legs extended and adducted. Bend elbows and start rolling up, stretching arms with the legs simultaneously
13–24	Push–through with feet (Cadillac)	Lie on back, head toward the push bar. Bend knees and pull the bar in toward the torso, lengthen the legs, and lift hips to bring the bar toward the ceiling

PFMC group had a mean age of 28.25 years (SD ± 5,8). The homogeneity of the groups was confirmed with a p value of only 0.4053. In terms of BMI, the PEP group had an average of 23.68 kg/cm^2 (SD ± 3.4) whereas the other group had 22.52 kg/cm^2 (SD ± 2.4). The homogeneity of the groups was confirmed with a p value of 0.17. In terms of ethnicity, the PEP group and the other group had the same percentage: 83.3 % were Caucasian. The homogeneity of the groups was confirmed with a p value of 1.00. In terms of education, in the PEP group 58.3 % had finished the bachelor's degree whereas in the other group 66.7 % had finished the bachelor's degree. The homogeneity of the groups was confirmed with a p value of only 0.551.

Furthermore, when studying the Oxford Scale, the PEP group had a mean of 3.33 (SD ± 0.82) and a median of 3.00 whereas the PEP + PFMC group had 3.54 (SD ± 0.72) and a median of 3.50. Comparing the groups, the homogeneity test also validated their uniformity with a p value of 0.165. The results mentioned before revealed that both groups had been uniform, for there was no significant statistical difference equal or higher than 5 % reliability.

Table 2 Pre-treatment characteristics of Pilates exercise program (PEP) versus PEP + pelvic floor muscle contraction (PFMC) groups before any patients dropped out of the study

Variable	PEP (n = 28)	PEP + PFMC (n = 29)	p
Age (years)	27.41 ± 4.8	27.98 ± 5.4	0.3173*
BMI (kg/cm^2)	23.60 ± 3.1	23.01 ± 2.8	0.1853*
Caucasian	85.7 %	82.8 %	0.760**
Bachelor's degree	60.7 %	69.0 %	0.514**

Data are presented as mean ± SD

*Student's t test

**Chi-squared test

To compare the Oxford Scale before and after treatment for both groups we used the Mann–Whitney U test. Although both groups had the same median, their distributions were different. Comparing the groups, the result was a p value lower than 5 %, which rejects the null hypothesis of equality (Table 4).

Only the variables of the Oxford Scale were homogeneous for both groups before treatment. When considering other variables as they were not homogeneous, the test based on the mean of the differences between before and after treatment were applied for each group.

The groups were not homogeneous, thus, the test focused on verifying if one group showed increased results between the after and before more than the other. To estimate this to one specific variable, first we calculated for each subject the

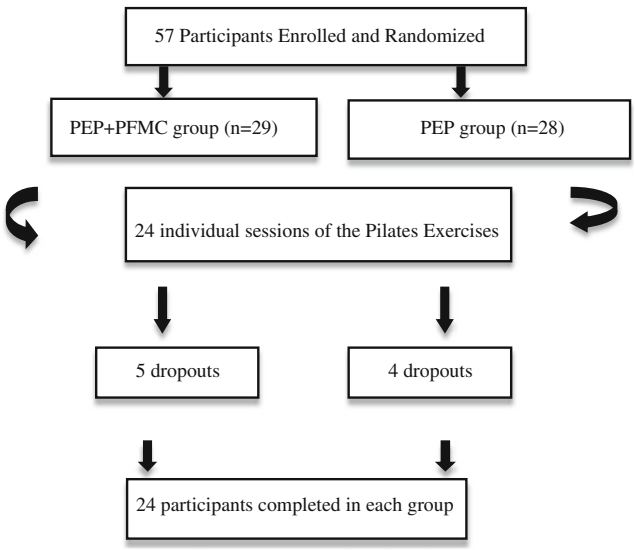

Fig. 2 Flow diagram of enrollment and drop-out

Table 3 Distribution of patients based on demographic characteristics before the initiation and termination of treatment

Variable	PEP ($n=24$)	PEP + PFMC ($n=24$)	p
Age (years)	26.96 ± 4.8	28.25 ± 5.8	0.4053*
BMI (kg/cm^2)	23.68 ± 3.4	22.52 ± 2.4	0.1753*
Oxford Scale	3.54 ± 0.72	3.33 ± 0.82	0.165**
Caucasian	83.3 %	83.3 %	1.000**
Bachelor's degree	58.3 %	66.7 %	0.551**

Data are presented as mean ± SD

*Student's *t* test

**Mann–Whitney *U* test

difference between the after and the before treatment result. Second, we estimated the mean of these differences for each group. Last, we used Student's *t* test to determine if the mean was equal or different.

All other results related to continuous quantitative variables, considering the Student's *t* test, analyzed pelvic floor strength. Based on these results, the PEP + PFMC group showed better improvements, compared with the PEP group, in terms of both peak and average pressures. The same improvement was observed in the measurement of pubovisceral muscle thickness at contraction (Table 5). On the other hand, the variables of pubovisceral muscle thickness at rest and the genital hiatus area (both at rest and during contraction), did not indicate any sign of improvement when the data collected before and after the Pilates protocol had been analyzed, considering the significance level of 5 % when comparing the two groups.

Discussion

In our study, the addition of a voluntary PFMC to a PEP was more effective than Pilates alone in improving PFM strength in sedentary nulliparous women compared with Pilates exercises without PFM contraction.

Pilates exercises are used to provide greater strength and flexibility. It is related to physical fitness and the association between body mind, spirit, good posture, flexibility and vitality [17]. The exercises of Pilates include the activation of PFM and the effects of this relationship have been investigated in various studies in healthy women [4, 18, 19].

Table 4 Comparison of the mean Oxford Scale differences before and after treatment in the two groups

Variable	Group	Median	Mean	SD	p value
Oxford Scale	PEP + PFMC	4.00	4.29	0.62	0.000*
	PEP	4.00	3.58	0.65	

Culligan et al. [4] performed a similar RCT study including 62 women recruited to Pilates or PFMT. Each group had 24 bi-weekly sessions of Pilates exercises. The PFM strength was measured using vaginal pressure equipment. The group undergoing Pilates training improved muscle strength similar to the PFMT group. Based on their results, they suggested that this "may eventually lead to widespread use of Pilates-based exercise programs to treat and prevent pelvic floor dysfunction." We highlighted that our results should be restricted to analyzing the effects on PFM strength exclusively in sedentary healthy nulliparous women.

Our findings suggest that Pilates exercises associated with voluntary PFM contraction may improve PFM strength and pubovisceral thickness in healthy sedentary nulliparous women. Additionally, we agree that Pilates alone does not overcome the effects of adding the voluntary PFM contraction, even when the women are capable of performing this contraction correctly before starting any exercise session. From our perspective, these findings should be discussed with caution. From a clinical point of view, both groups have started from Oxford grade 3, corresponding to a good PFM contraction. After treatment, the PEP + PFMC group increased their grade from 3 to 4, which changed their results from moderate to good muscle contraction, whereas the PEP group had stayed the same. Based on these results, we highlight that women who cannot correctly contract the PFM may not gain the same benefits of Pilates exercises as our study participants. Thus, one question remains: what would be the effect of Pilates in women who are not able to contract their PFM?

It is widely known that Pilates training is directly related to transversus abdominis activation during functional activities and exercises [20]. Other alternative regimens can also activate these muscles, and consequently the PFM, such as the abdominal hypopressive technique (AHT). Our team has studied the impact on PFM during AHT in previous studies, both on evaluation and treatment. Stüpp et al. [21] evaluated healthy nulliparous women and showed that AHT was less effective than voluntary PFM contraction alone measured with vaginal surface EMG and there was no additional effect of adding the AHT to the PFM contraction. Similar findings was observed in two RCT studies that included AHT in the treatment of women with pelvic organ prolapse [22, 23]. Based on our previous studies, we do not recommend the use of other regimens because none of them can surpass the benefits of PFMT via transversus abdominis activation or training.

According to our findings, one study developed a complete systematic review and critically appraised the current evidence of the effectiveness of an alternative to PFM training to treat both stress urinary incontinence and mixed urinary incontinence [5]. The authors concluded that the efficacy of

Table 5 Comparison of the mean differences before and after treatment in the two groups

Variable	PEP ($n = 24$)	PEP + PFMC ($n = 24$)	p value
Peak of pressure (cm H_2O)	2.12 (7.99)	6.95 (11.50)	0.049*
Average pressure (cm H_2O)	1.00 (5.60)	4.69 (9.17)	0.050*
PM thickness at rest (cm)	0.08 (0.25)	0.10 (0.26)	0.398
PM thickness at contraction (cm)	0.02 (0.32)	0.16 (0.25)	0.046*
Levator hiatus area at rest (cm^2)	0.32 (2.03)	0.61 (2.47)	0.326
Levator hiatus area at contraction (cm^2)	−0.01 (1.82)	−0.58 (2.42)	0.182

*$P < 0.05$ indicates a significant difference; Student's t test

PM pubovisceral muscle, *PEP* Pilates exercise program, *PEP+ PFMC* Pilates exercise program with PFMC

either abdominal training or Pilates in preventing or treating stress urinary incontinence as an alternative or an adjunct to PFM training has not yet been conclusively demonstrated.

It is widely described that many healthy and incontinent women are not able to contract their PFM. The PFM must contract during tasks that elevate intra-abdominal pressure (IAP) to contribute to a pressure increase and to maintain continence [24] .

In the same way, increased intra-abdominal pressure is considered a risk factor for developing PFM dysfunctions, such as prolapse and urinary incontinence, and women are generally recommended to avoid straining [18, 25]. It is important that the activity levels and timing of onsets between the diaphragm and transversus with the PFM are well balanced during the increased IAP [17].

Often, women with and without PFM dysfunction choose the Pilates as a physical activity and perform these exercises regularly. The Pilates exercises are performed with the women fully clothed and some of the professionals try to monitor the PFM contraction by inspection, which is a difficult task. The evaluation of PFM function by the specialized physiotherapists includes invasive techniques, requiring their patients to be undressed to process this technique.

Based on the information mentioned above, a partnership between a professional who works daily with Pilates and a Pilates teacher specialized in PFM rehabilitation could be positive. Specific evaluation of the PFM before starting any exercise session may provide information regarding the potential risk of pelvic floor injuries, in addition to facilitating the selection of which type of Pilates exercise could be indicated in each woman. Moreover, it could help the professional to decide if a patient is already able to start any exercise session or if there is any muscle improvement needed.

We highlight the need for high-quality randomized trials specially designed to evaluate whether Pilates exercises can promote benefits to women with pelvic floor dysfunctions, before this alternative intervention become routine clinical practice. Also, one important limitation of this study must be considered. Although we did meet our desired sample size of 24 participants per group (and therefore achieved our desired power), this study was relatively small.

Our findings suggest that adding a voluntary PFM contraction to a Pilates exercise program is more effective than Pilates alone in improving PFM strength in sedentary nulliparous women.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

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