

The Effects of Three Different Pilates Methods on Pelvic Floor Muscle Function: A Randomized Comparative Interventional Study

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Research Article

Keywords: Pelvic floor muscles, Reformer Pilates, Mat Pilates, perineometry, core endurance

Posted Date: March 26th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-8920061/v1>

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Additional Declarations: No competing interests reported.

Abstract

Objective

This study examined the effects of Reformer Pilates, Mat Pilates, and home-based exercise programs on pelvic floor muscle (PFM) function, as well as core and hip muscle endurance, in healthy women.

Methods

Forty-eight women aged 18–45 years were randomly assigned to Reformer Pilates (n = 14), Mat Pilates (n = 19), or Home Exercise (n = 15). All participants completed a 10-week program with two sessions per week. PFM strength was assessed using a Peritron™ perineometer in four positions, endurance in the hook-lying position, core endurance with McGill tests, and hip endurance with the single-leg abduction test.

Results

Both Reformer and Mat Pilates groups showed significant improvements across pelvic floor, core, and hip outcomes ($p < 0.05$), whereas no changes were observed in the Home Exercise group ($p > 0.05$). Reformer Pilates demonstrated the greatest gains in PFM strength ($\Delta = +6.50$ mmHg, $p < 0.001$, $\eta^2 = 0.691$) and endurance ($\Delta = +6.00$ s, $p < 0.001$, $\eta^2 = 0.540$). Mat Pilates also improved PFM strength ($\Delta = +3.63$ mmHg, $p < 0.001$, $\eta^2 = 0.406$) and endurance ($\Delta = +2.65$ s, $p < 0.001$). For core flexor endurance, Reformer ($\Delta = +16.85$ s, $p < 0.001$, $\eta^2 = 0.352$) and Mat Pilates ($\Delta = +8.68$ s, $p < 0.001$) produced greater improvements than Home Exercise. Hip endurance increased more in Reformer ($\Delta = +16.28$ s, $p < 0.001$, $\eta^2 = 0.459$) and Mat Pilates ($\Delta = +14.52$ s, $p < 0.001$) compared with Home Exercise.

Conclusions

Reformer Pilates was the most effective method for enhancing PFM function, while Mat Pilates was superior to home-based training. Both Pilates methods similarly improved core and hip endurance.

Trial registration

ClinicalTrials.gov, NCT07212621. Registered September 23, 2025.

HIGHLIGHTS

- Reformer Pilates emerged as the most effective method for enhancing pelvic floor muscle strength and endurance.
- Mat Pilates offered an effective alternative due to its low cost and equipment-free applicability.
- Home exercises did not lead to significant improvements in pelvic floor function or muscular endurance.
- Different Pilates approaches produce distinct physiological outcomes in terms of their contributions to pelvic floor health.

INTRODUCTION

Pelvic floor muscles play a critical role in women's health by contributing to continence, supporting pelvic organs, and maintaining spinal stability¹. Weakness in these muscles can lead to significant clinical issues such as stress urinary incontinence, pelvic organ prolapse, low back pain, and postural disorders². Factors such as aging, pregnancy, childbirth, hormonal changes, obesity, and a sedentary lifestyle can weaken the pelvic floor muscles (PFMs). In particular, the decline in estrogen levels during menopause reduces connective tissue elasticity, thereby diminishing the supportive capacity of the pelvic structures³.

Traditionally, pelvic floor muscle training and Kegel exercises have been widely used in women to strengthen the PFMs⁴. In recent years, Pilates exercises—particularly those that enhance core stability and adopt a holistic approach—have attracted increasing attention for their potential effects on the pelvic floor⁵. The literature reports that Pilates exercises can enhance postural control by promoting functional integration between the hip and core muscles and the pelvic floor⁶. While Mat Pilates is a bodyweight-based method that

does not require equipment, Reformer Pilates utilizes spring-resistance systems to achieve a higher level of muscle activation^{7–9}. However, there is a limited number of controlled studies in the literature that compare the effects of these methods on pelvic floor function. Although the effects of various Pilates approaches on pelvic floor, core, and hip endurance have been examined individually, few studies have assessed these methods within an integrated intervention protocol. In addition to this gap, it is noteworthy that there is a lack of studies directly comparing the effectiveness of individually administered home exercise protocols with programs conducted under clinical supervision^{4,10}.

This study aimed to compare the effects of Mat Pilates, Reformer Pilates, and home-based exercises on pelvic floor muscle strength and endurance, as well as core and hip muscular endurance.

METHODS

Study Design and Ethical Approval

This randomized comparative interventional study was approved by the relevant institutional ethics committee (Approval No: XXX). All procedures were conducted in accordance with the principles of the Declaration of Helsinki. The study was carried out between January and May 2025 and was registered at ClinicalTrials.gov (Identifier: XXX).

Participants and Randomization

Participants were recruited between January and May 2025 through community-based announcements and referrals. Women who expressed interest in participating were initially screened for eligibility via a structured interview conducted by a physiotherapist. Individuals who met the inclusion criteria and provided written informed consent were enrolled in the study.

The study included 48 female participants between the ages of 18 and 45 who were healthy in terms of pelvic floor function. Inclusion criteria required that participants be women who had not engaged in regular Pilates or any form of exercise for at least one year, had no history of more than three deliveries, had not been diagnosed with pelvic organ prolapse or undergone pelvic floor surgery, and did not have any neurological, orthopedic, cardiovascular, or psychiatric conditions. Participants were required to attend the exercise sessions regularly. Exclusion criteria included being in the menopausal period, having given birth within the past six months, engaging in regular physical activity, experiencing severe incontinence symptoms, having a body mass index greater than 35, and lacking motivation. Individuals with neurological, orthopedic, cardiovascular, or psychiatric disorders were also excluded. Participants were randomly assigned to the Mat Pilates (n = 19), Reformer Pilates (n = 14), and Home Exercise (n = 15) groups using a computer-assisted randomization procedure based on a random number table generated with SPSS (Statistical Package for the Social Sciences) software. The allocation was performed by an independent assistant not involved in the study, using a sealed envelope method (Fig. 1).

Assessment Methods

Pelvic floor muscle strength and endurance, as well as core and hip muscle endurance of the participants, were assessed twice-before and after the 10-week exercise training by expert physiotherapists under sterile conditions and with participant confidentiality maintained.

1- Demographic Data Form

Age, height, weight, number of deliveries, type of delivery, history of episiotomy, and dominant extremity information were collected using the sociodemographic data form.

2- Assessment of Pelvic Floor Muscle Strength and Endurance

Pelvic floor muscle function was assessed using the Peritron™ 9300 perineometer device (Cardio Design, Australia), which includes a sterile, single-use vaginal probe. This device objectively measures pelvic floor muscle strength and endurance by recording changes in intravaginal pressure in mmHg. It provides real-time feedback via a digital display and has been clinically validated for its high measurement sensitivity¹¹.

Measurement Protocol

Three consecutive measurements were taken in each testing position. To allow recovery of the pelvic floor muscles between measurements, the probe was removed and reinserted, with an approximate 30-second rest period provided during this process¹². Additionally, a rest interval of approximately 90 seconds was allowed between changes in testing positions¹³. The arithmetic mean of the three measurements obtained in each position was used for analysis. Measurements were conducted in four different positions

1. Assessment of Pelvic Floor Muscle Strength and Endurance in the Hook-lying Position

Participants were positioned in a supine position with knees flexed at approximately 90° and feet flat on the floor. In this position, the maximum contraction strength of the pelvic floor muscles (measured in mmHg) was determined, and the duration for which the maximum contraction could be sustained was measured in seconds to record endurance values.

2. Assessment of Pelvic Floor Muscle Strength in the Hip Abduction Position

While the participant was lying in a supine position, the hips were positioned at approximately 30° of abduction and the knees were maintained in an open position. During this setup, pelvic floor muscle functions were assessed, and vaginal intraluminal pressure data generated during maximum contraction were recorded¹⁴.

3. Assessment of Pelvic Floor Muscle Strength in the Hip Adduction Position

While in the supine position, the participant was instructed to squeeze a small Pilates ball (diameter: 15–20 cm) placed between the knees with maximum force. During this task, pelvic floor muscle strength and endurance were measured, and the values generated during maximum contraction were recorded¹⁴.

4. Assessment of Pelvic Floor Muscle Strength in the Curl-Up Position (Measurement Under Abdominal Muscle Activation)

While lying in the supine position with the legs in a hook-lying position, the participant was instructed to engage the abdominal muscles and move into a crunch position. During this active abdominal contraction, pelvic floor muscle (PFM) strength was measured using a perineometer. The vaginal pressure generated during maximum PFM contraction was recorded. The use of perineometric assessment in the crunch position has not been explicitly defined in the existing literature (Fig. 2).

3- Assessment of Core Muscle Endurance

Core muscle endurance of the participants was assessed using the McGill Core Endurance Test Battery, which includes the flexor (forearm plank), extensor (trunk extension), and lateral (side plank) endurance tests. In the side plank test, only the dominant extremity was evaluated. For each test, participants were instructed to maintain the designated position for as long as possible without experiencing pain or compensatory movements. The duration was recorded in seconds and used as a performance indicator¹⁵.

4- Assessment of Hip Muscle Endurance

Muscular endurance of the hip region was assessed using the single-leg abduction test. Participants were asked to lie on their side with the dominant limb positioned on top. Maintaining full knee extension and 30° of hip abduction, they were instructed to hold this position throughout the test. The test continued until pain, fatigue, loss of position, or pelvic rotation occurred, and the maximum duration was recorded in seconds¹⁶.

Training Program

All three groups participated in exercise sessions lasting approximately 45 minutes, twice a week for a duration of 10 weeks. Each exercise set consisted of 10–12 repetitions. The exercises were performed at a low to moderate pace, with a 30-second passive rest period between each exercise. The same exercise protocol was implemented across all groups.

Mat Pilates Group: Participants performed the exercises—Hundred, Cobra, Bridge, Clamshell, Cat-Cow, Swimming, Roll-Up, and Toe Taps—in groups of five under the supervision of a physiotherapist. Each exercise was performed for 10 repetitions, with modifications introduced as needed based on individual suitability and progression⁸.

Reformer Pilates Group: Participants in this group performed the aforementioned Pilates exercises using a Reformer device from the BodyTech series. The sessions were conducted in groups of three under the supervision of a physiotherapist⁹.

Home Exercise Group: Following one-on-one instruction, participants independently performed the same exercise protocol (Hundred, Cobra, Bridge, Clamshell, Cat-Cow, Swimming, Roll-Up, and Toe Taps) at home twice per week, guided by written and visual materials. To ensure accurate and consistent adherence to the exercise program, brief voice feedback was collected weekly via a mobile messaging application. Exercise frequency, perceived difficulty level, and any potential issues were evaluated by the physiotherapist⁵.

STATISTICAL ANALYSIS

Statistical analyses were conducted using SPSS version 26.0. Normality of the data was assessed through skewness-kurtosis values and the Shapiro-Wilk test. When assumptions of normality were met, one-way ANOVA and paired t-tests were used; for non-normally distributed data, the Kruskal-Wallis and Wilcoxon tests were applied. Categorical variables were analyzed using the Chi-square test. For comparisons where a significant difference was identified, effect size was calculated, and Bonferroni correction was applied for multiple comparisons. Effect sizes were interpreted as follows: for Cohen's d , < 0.20 was considered small, $0.20-0.79$ moderate, and ≥ 0.80 large; for eta squared (η^2), < 0.01 small, $0.01-0.13$ moderate, and ≥ 0.14 large; and for the correlation coefficient (r), < 0.10 small, $0.10-0.49$ moderate, and ≥ 0.50 large. A significance level of $p < 0.05$ was adopted. For the sample size calculation related to pelvic floor muscle strength—one of the primary outcome variables of the study—the effect size was determined as Cohen's $f = 0.85$, based on the mean and standard deviation values reported in a previous study with a similar design. Based on this effect size, an a priori power analysis was conducted using a 5% significance level ($\alpha = 0.05$) and 80% statistical power ($1 - \beta = 0.80$), which indicated that a minimum of 17 participants per group was required. The power analysis was performed using G*Power 3.1 software¹⁷.

RESULTS

The study was conducted with a total of 48 participants, including 15 (31.3%) in the Home Exercise group, 19 (39.6%) in the Mat Pilates group, and 14 (29.2%) in the Reformer Pilates group. Between-group comparisons of participants' sociodemographic and obstetric characteristics are presented in Table 1. No significant differences were found among the groups in terms of demographic variables; however, the average number of stillbirths was significantly higher in the Mat Pilates group compared to the Reformer Pilates group ($p = 0.027$, $f/x^2 = 0.115$).

Table 1
Between-Group Comparisons of Participants' Sociodemographic Characteristics and Obstetric History

Between-Group Comparisons of Participants' Sociodemographic Characteristics and Obstetric History												
		Total (n = 48)		Home Exercise (n = 15)		Mat Pilates (n = 19)		Reformer Pilates (n = 14)		f/x ²	P	η ² (GA)
		Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Age		41.14	6.946	41.80	7.830	40.63	5.658	41.14	7.950	0.083 ¹	0.960	-
Height		163.39	5.233	163.86	5.553	162.31	5.033	164.35	5.271	0.692 ²	0.506	-
Weight		65.54	9.615	66.93	10.215	62.15	6.618	68.64	11.486	2.164 ²	0.127	-
BMI		24.58	3.527	24.95	3.566	23.65	2.770	25.44	4.290	1.176 ²	0.318	-
Gravida		2.54	1.287	2.26	1.032	3.05	1.544	2.14	0.949	2.690 ²	0.079	-
Parity		1.79	0.650	1.80	0.676	1.78	0.630	1.78	0.699	0.002 ²	0.998	-
Stillbirth		0.31	0.589	0.20	0.414	0.57	0.768	0.07	0.267	7.214 ¹	0.027	0.115
Abortion		0.43	0.711	0.26	0.593	0.68	0.820	0.28	0.611	4.673 ¹	0.097	-
		N	%	N	%	n	%	n	%			
Mode of Delivery	Vaginal	28	58.3	6	40.0	12	63.2	10	71.4	3.244 ³	0.198	-
	Cesarean section	20	41.7	9	60.0	7	36.8	4	28.6			
Episiotomy	Yes	16	33.3	4	26.7	7	36.8	5	35.7	0.441 ³	0.802	-
	No	32	66.7	11	73.3	12	63.2	9	64.3			
¹Kruskal-Wallis Test ²ANOVA Test ³Chi-Square Test												
*p < 0.05 significance level												
*Effect sizes were interpreted as follows: for eta squared (η²), < 0.01 = small, 0.01–0.13 = moderate, ≥ 0.14 = large												
*n: sample size; cm: centimeter; BMI: body mass index; kg: kilogram; kg/m²: kilogram per square meter; %: percentage; SD: standard deviation												

Pre-test comparisons of the participants are presented in Table 2. The endurance level of the Pelvic Floor Muscles (PFM) in the hook-lying position was found to be statistically higher in the Home Exercise group, with a moderate effect size observed for this difference (p = 0.037, f/x² = 0.136).

Table 2
Baseline Assessment of Pelvic Floor Muscle Function Core And Hip Muscle Endurance in the Participants

Variables	Group	N	Mean	SD	Median	f/x ²	P	η ²	Difference
Pelvic floor muscle strength in hook-lying position (mmHg)	Home Exercise ¹	15	13.86	4.911	24.30	1.392	0.259	-	-
	Mat Pilates ²	19	15.10	3.680	28.29				
	Reformer Pilates ³	14	12.50	4.847	19.57				
Pelvic floor muscle endurance in hook-lying position (sec)	Home Exercise ¹	15	7.06	6.111	28.03	3.542	0.037	0.136	2 < 1
	Mat Pilates ²	19	3.28	1.294	20.50				
	Reformer Pilates ³	14	6.21	4.854	26.14				
Pelvic floor muscle strength in hip abduction position (mmHg)	Home Exercise ¹	15	14.86	4.517	28.33	2.821 ¹	0.244	-	-
	Mat Pilates ²	19	13.05	4.539	20.53				
	Reformer Pilates ³	14	14.35	4.634	25.79				
Pelvic floor muscle strength in hip adduction position (mmHg)	Home Exercise ¹	15	14.66	4.287	27.53	1.280 ¹	0.527	-	-
	Mat Pilates ²	19	13.26	4.544	22.11				
	Reformer Pilates ³	14	14.00	4.489	24.50				
Pelvic floor muscle strength in crunch position (mmHg)	Home Exercise ¹	15	13.53	4.307	27.03	1.859	0.168	-	-
	Mat Pilates ²	19	11.57	4.451	19.55				
	Reformer Pilates ³	14	14.21	3.378	28.50				
Lateral Endurance (sec)	Home Exercise ¹	15	32.40	15.824	26.57	0.573	0.568	-	-
	Mat Pilates ²	19	27.36	15.373	21,58				
	Reformer Pilates ³	14	32.42	16.882	26.25				
Extensor Endurance (sec)	Home Exercise ¹	15	37.53	20.869	22.80	1.020	0.369	-	-
	Mat Pilates ²	19	48.05	30.830	26.55				
¹ Kruskal-Wallis Test : (f/x ²)									
• p < 0.05 significance level									
*Effect size thresholds: Cohen's d (< 0.20 small; 0.20–0.79 moderate; ≥0.80 large); η ² (< 0.01 small; 0.01–0.13 moderate; ≥0.14 large); r (< 0.10 small; 0.10–0.49 moderate; ≥0.50 large)									
*n: sample size; sec: second; SD: standard deviation									

Variables	Group	N	Mean	SD	Median	f/x ²	P	η ²	Difference
	Reformer Pilates ³	14	37.64	18.669	23.54				
Flexor Endurance (sec)	Home Exercise ¹	15	33.66	19.995	23.20	0.696 ¹	0.706	-	-
	Mat Pilates ²	19	39.47	21.670	26.58				
	Reformer Pilates ³	14	33.64	19.165	23.07				
Hip Endurance (sec)	Home Exercise ¹	15	39.26	20.967	23.93	1.276 ¹	0.528	-	-
	Mat Pilates ²	19	50.10	36.360	27.08				
	Reformer Pilates ³	14	33.78	18.564	21.61				
¹ Kruskal-Wallis Test : (f/x ²)									
• <i>p</i> < 0.05 significance level									
*Effect size thresholds: Cohen's d (< 0.20 small; 0.20–0.79 moderate; ≥0.80 large); η ² (< 0.01 small; 0.01–0.13 moderate; ≥0.14 large); r (< 0.10 small; 0.10–0.49 moderate; ≥0.50 large)									
*n: sample size; sec: second; SD: standard deviation									

According to the data analyses presented in Table 3, no significant difference was observed between the pre- and post-test measurements in the Home Exercise group ($p > 0.05$). In contrast, significant improvements were found across all variables in both the Mat Pilates and Reformer Pilates groups ($p < 0.05$). In the Mat Pilates group, large effect sizes were observed for PFME HLP ($d = -0.571$), PFMS CP ($d = -0.843$), and Hip Endurance ($d = -0.610$). Moderate effect sizes were observed for PFMS HLP ($d = -0.479$), PFMS HABD ($d = -0.347$), PFMS HADD ($d = -0.390$), Lateral ($d = -0.428$), Extensor ($d = -0.388$), and Flexor Endurance ($d = -0.434$). In the Reformer Pilates group, large effect sizes were observed for PFMS HLP ($d = -1.561$), PFME HLP ($d = -1.317$), PFMS HADD ($d = -0.517$), PFMS CP ($d = -1.002$), Flexor Endurance ($d = -1.183$), and Hip Endurance ($d = -0.519$). Moderate effect sizes were observed for PFMS HABD ($d = -0.454$), Lateral Endurance ($d = -0.429$), and Extensor Endurance ($d = -0.453$).

Table 3
Comparison of Participants' Pre- and Post-Intervention Outcomes

Variable	Test	N	Mean	Standard Deviation	t/z	p	d/r
Home Exercise							
Pelvic floor muscle strength in hook-lying position (mmHg)	Pre-Test	15	13.86	4.911	1.000	0.334	-
	Post-Test	15	13.73	4.963			
Pelvic floor muscle endurance in hook-lying position (sec)	Pre-Test	15	7.06	6.111	-0.642	0.531	-
	Post-Test	15	7.26	5.969			
Pelvic floor muscle strength in hip abduction position (mmHg)	Pre-Test	15	14.86	4.517	-0.3781	0.705	-
	Post-Test	15	15.00	5.437			
Pelvic floor muscle strength in hip adduction position (mmHg)	Pre-Test	15	14.66	4.287	-1.0001	0.317	-
	Post-Test	15	14.73	4.300			
Pelvic floor muscle strength in crunch position (mmHg)	Pre-Test	15	13.53	4.307	-1.146	0.271	-
	Post-Test	15	13.73	4.078			
Lateral Endurance (sec)	Pre-Test	15	32.40	15.824	-0.822	0.425	-
	Post-Test	15	32.86	16.753			
Extensor Endurance (sec)	Pre-Test	15	37.53	20.869	-1.293	0.217	-
	Post-Test	15	38.06	21.939			
Flexor Endurance (sec)	Pre-Test	15	33.66	19.995	-1.382	0.189	-
	Post-Test	15	33.86	19.769			
Hip Endurance (sec)	Pre-Test	15	39.26	20.967	1.103	0.289	-
	Post-Test	15	38.13	17.755			
Mat Pilates							
Pelvic floor muscle strength in hook-lying position (mmHg)	Pre-Test	19	15.10	3.680	-2.9581	0.003	-0.479
	Post-Test	19	18.73	12.861			
Pelvic floor muscle endurance in hook-lying position (sec)	Pre-Test	19	3.28	1.294	-3.5261	p < 0.001	-0.571
	Post-Test	19	5.94	3.807			
Pelvic floor muscle strength in hip abduction position (mmHg)	Pre-Test	19	13.05	4.539	-2.1421	0.032	-0.347
	Post-Test	19	15.05	4.440			
Pelvic floor muscle strength in hip adduction position (mmHg)	Pre-Test	19	13.26	4.544	-2.4051	0.016	-0.390
	Post-Test	19	14.84	4.991			
Pelvic floor muscle strength in crunch position (mmHg)	Pre-Test	19	11.57	4.451	-3.674	0.002	-0.843
	Post-Test	19	14.78	4.429			
¹Wilcoxon Signed-Rank Test							
*p < 0.05 significance level							
*Effect sizes were interpreted as follows: for Cohen’s d, < 0.20 = small, 0.20–0.79 = moderate, ≥ 0.80 = large; for eta squared (η²), < 0.01 = small, 0.01–0.13 = moderate, ≥ 0.14 = large; for correlation coefficient (r), < 0.10 = small, 0.10–0.49 = moderate, ≥ 0.50 = large							
*PFM: pelvic floor muscle; sec: second; mmHg: millimeters of mercury; n: sample size							

Variable	Test	N	Mean	Standard Deviation	t/z	p	d/r
Home Exercise							
Lateral Endurance (sec)	Pre-Test	19	27.36	15.373	-2.6411	0.008	-0.428
	Post-Test	19	34.10	18.600			
Extensor Endurance (sec)	Pre-Test	19	48.05	30.830	-2.3951	0.017	-0.388
	Post-Test	19	57.89	28.126			
Flexor Endurance (sec)	Pre-Test	19	39.47	21.670	-2.6781	0.007	-0.434
	Post-Test	19	48.15	21.247			
Hip Endurance (sec)	Pre-Test	19	50.10	36.360	-3.7651	p < 0.001	-0.610
	Post-Test	19	64.63	39.985			
Reformer Pilates							
Pelvic floor muscle strength in hook-lying position (mmHg)	Pre-Test	14	12.50	4.847	-5.840	p < 0.001	-1.561
	Post-Test	14	19.00	3.961			
Pelvic floor muscle endurance in hook-lying position (sec)	Pre-Test	14	6.21	4.854	-4.926	p < 0.001	-1.317
	Post-Test	14	12.21	6.241			
Pelvic floor muscle strength in hip abduction position (mmHg)	Pre-Test	14	14.35	4.634	-2.8011	0.005	-0.454
	Post-Test	14	22.64	8.270			
Pelvic floor muscle strength in hip adduction position (mmHg)	Pre-Test	14	14.00	4.489	-3.1911	0.001	-0.517
	Post-Test	14	24.14	7.123			
Pelvic floor muscle strength in crunch position (mmHg)	Pre-Test	14	14.21	3.378	-3.750	0.002	-1.002
	Post-Test	14	20.85	6.825			
Lateral Endurance (sec)	Pre-Test	14	32.42	16.882	-2.6461	0.008	-0.429
	Post-Test	14	40.71	16.762			
Extensor Endurance (sec)	Pre-Test	14	37.64	18.669	-2.7941	0.005	-0.453
	Post-Test	14	54.78	11.781			
Flexor Endurance (sec)	Pre-Test	14	33.64	19.165	-4.426	0.001	-1.183
	Post-Test	14	50.50	13.001			
Hip Endurance (sec)	Pre-Test	14	33.78	18.564	-3.2031	0.001	-0.519
	Post-Test	14	50.07	19.056			
¹Wilcoxon Signed-Rank Test							
*p < 0.05 significance level							
*Effect sizes were interpreted as follows: for Cohen’s d, < 0.20 = small, 0.20–0.79 = moderate, ≥ 0.80 = large; for eta squared (η²), < 0.01 = small, 0.01–0.13 = moderate, ≥ 0.14 = large; for correlation coefficient (r), < 0.10 = small, 0.10–0.49 = moderate, ≥ 0.50 = large							
*PFM: pelvic floor muscle; sec: second; mmHg: millimeters of mercury; n: sample size							

An examination of the participants' post-test values in Table 4 revealed significant differences between groups in the variables PFMS HLP ($\eta^2 = 0.158$), PFME HLP ($\eta^2 = 0.240$), PFMS HABD ($\eta^2 = 0.172$), PFMS HADD ($\eta^2 = 0.387$), PFMS CP ($\eta^2 = 0.266$), Extensor Endurance ($\eta^2 = 0.123$), and Flexor Endurance ($\eta^2 = 0.134$) ($p < 0.05$). For the PFMS HLP variable, the mean score of the Reformer Pilates group was

significantly higher than that of the Home Exercise group, with a moderate effect size. Similarly, in both the Extensor and Flexor Endurance variables, the Reformer group demonstrated higher mean values compared to the Home Exercise group, with moderate effect sizes observed in both cases. On the other hand, for the variables PFME HLP ($\eta^2 = 0.240$), PFMS HABD ($\eta^2 = 0.172$), PFMS HADD ($\eta^2 = 0.387$), and PFMS CP ($\eta^2 = 0.266$), the Reformer Pilates group exhibited higher mean values compared to both the Home Exercise and Mat Pilates groups. These differences were found to have large effect sizes.

Table 4
Post-Intervention Between-Group Comparisons of Pelvic Floor Muscle Function Core and Hip Muscle Endurance

Variable	Group	n	Mean	SD	Median	f/x ²	p	η ²	Difference
Pelvic floor muscle strength in hook-lying position (mmHg)	Home Exercise ¹	15	13.73	4.963	17.13	9.126 ¹	0.010	0.158	1 < 3
	Mat Pilates ²	19	18.73	12.861	24.29				
	Reformer Pilates ³	14	19.00	3.961	32.68				
Pelvic floor muscle endurance in hook-lying position (sec)	Home Exercise ¹	15	7.26	5.969	20.47	12.821 ¹	0.002	0.240	1 < 3 2<3
	Mat Pilates ²	19	5.94	3.807	19.45				
	Reformer Pilates ³	14	12.21	6.241	35.68				
Pelvic floor muscle strength in hip abduction position (mmHg)	Home Exercise ¹	15	15.00	5.437	19.70	9.753 ¹	0.008	0.172	1 < 3 2<3
	Mat Pilates ²	19	15.05	4.440	21.11				
	Reformer Pilates ³	14	22.64	8.270	34.25				
Pelvic floor muscle strength in hip adduction position (mmHg)	Home Exercise ¹	15	14.73	4.300	18.83	19.438 ¹	p < 0.001	0.387	1 < 3 2<3
	Mat Pilates ²	19	14.84	4.991	18.82				
	Reformer Pilates ³	14	24.14	7.123	38.29				
Pelvic floor muscle strength in crunch position (mmHg)	Home Exercise ¹	15	13.73	4.078	19.17	8.168	0.001	0.266	1 < 3 2<3
	Mat Pilates ²	19	14.78	4.429	21.58				
	Reformer Pilates ³	14	20.85	6.825	34.18				
Lateral Endurance (sec)	Home Exercise ¹	15	32.86	16.753	22.37	1.945 ¹	0.378	0.041	-
	Mat Pilates ²	19	34.10	18.600	22.97				
	Reformer Pilates ³	14	40.71	16.762	28.86				
Extensor Endurance (sec)	Home Exercise ¹	15	38.06	21.939	16.30	7.577 ¹	0.023	0.124	1 < 3
	Mat Pilates ²	19	57.89	28.126	27.82				
¹Kruskal-Wallis Test: (f/x²)									
*p < 0.05 significance level									
*Effect sizes were interpreted as follows: for eta squared (η²), < 0.01 = small, 0.01–0.13 = moderate, ≥ 0.14 = large; for correlation coefficient (r), < 0.10 = small, 0.10–0.49 = moderate, ≥ 0.50 = large									
*n: sample size; sec: second; SD: standart deviation; χ²: chi-square; η²: eta squared (effect size); mmHg: millimeters of mercury									
*Group codes: 1 = Home Exercise; 2 = Mat Pilates; 3 = Reformer Pilates									

Variable	Group	n	Mean	SD	Median	f/x ²	p	η ²	Difference
	Reformer Pilates ³	14	54.78	11.781	28.79				
Flexor Endurance (sec)	Home Exercise ¹	15	33.86	19.769	17.27	3.495	0.039	0.134	1 < 3
	Mat Pilates ²	19	48.15	21.247	26.37				
	Reformer Pilates ³	14	50.50	13.001	29.71				
Hip Endurance (sec)	Home Exercise ¹	15	38.13	17.755	17.77	5.462 ¹	0.065	0.116	-
	Mat Pilates ²	19	64.63	39.985	28.89				
	Reformer Pilates ³	14	50.07	19.056	25.75				
¹Kruskal-Wallis Test: (f/x²)									
*p < 0.05 significance level									
*Effect sizes were interpreted as follows: for eta squared (η²), < 0.01 = small, 0.01–0.13 = moderate, ≥ 0.14 = large; for correlation coefficient (r), < 0.10 = small, 0.10–0.49 = moderate, ≥ 0.50 = large									
*n: sample size; sec: second; SD: standart deviation; χ²: chi-square; η²: eta squared (effect size); mmHg: millimeters of mercury									
*Group codes: 1 = Home Exercise; 2 = Mat Pilates; 3 = Reformer Pilates									

According to the Kruskal-Wallis analysis presented in Table 5, significant differences were found between groups for the following variables: PFMS HLP (η² = 0.691), PFME HLP (η² = 0.540), PFMS HABD (η² = 0.406), PFMS HADD (η² = 0.295), PFMS CP (η² = 0.254), Lateral Endurance (η² = 0.223), Extensor Endurance (η² = 0.340), Flexor Endurance (η² = 0.352), and Hip Endurance (η² = 0.459) (p < 0.05). For the PFMS HLP and PFME HLP variables, the Reformer Pilates group exhibited significantly higher mean values compared to both the Mat Pilates and Home Exercise groups, with the differences reflecting large effect sizes. For the variables PFMS HABD, PFMS CP, Lateral Endurance, Extensor Endurance, Flexor Endurance, and Hip Endurance, the mean values of both the Mat Pilates and Reformer Pilates groups were higher than those of the Home Exercise group. These differences were characterized by large effect sizes. For the PFMS HADD variable, the Reformer Pilates group demonstrated significantly higher values compared to both other groups, with a large effect size observed.

Table 5
Between-Group Comparison of Pre- and Post-Intervention Change Scores: Difference Analysis Findings

Variable	Group	n	Mean	SD	Mean	χ^2	p	η^2	Difference
Pelvic floor muscle strength in hook-lying position (mmHg)	Home Exercise ¹	15	-0.13	0.516	10.37	33.102	p < 0.001	0.691	1 < 2
	Mat Pilates ²	19	3.63	11.304	24.66				1 < 3
	Reformer Pilates ³	14	6.50	4.164	39.43				2<3
Pelvic floor muscle endurance in hook-lying position (sec)	Home Exercise ¹	15	0.20	1.207	11.43	26.318	p < 0.001	0.540	1 < 2
	Mat Pilates ²	19	2.65	3.253	24.97				1 < 3
	Reformer Pilates ³	14	6.00	4.557	37.86				2<3
Pelvic floor muscle strength in hip abduction position (mmHg)	Home Exercise ¹	15	0.13	1.407	13.13	20.275	p < 0.001	0.406	1 < 2
	Mat Pilates ²	19	2.00	5.916	24.76				1<3
	Reformer Pilates ³	14	8.28	7.183	36.32				
Pelvic floor muscle strength in hip adduction position (mmHg)	Home Exercise ¹	15	0.33	2.288	15.80	15.317	p < 0.001	0.295	1 < 3
	Mat Pilates ²	19	1.78	5.662	23.00				2<3
	Reformer Pilates ³	14	8.64	7.417	35.86				
Pelvic floor muscle strength in crunch position (mmHg)	Home Exercise ¹	15	0.20	0.676	14.03	13.467	0.001	0.254	1 < 2
	Mat Pilates ²	19	3.21	3.809	27.29				1<3
	Reformer Pilates ³	14	6.64	6.628	31.93				
Lateral Endurance Test (sec)	Home Exercise ¹	15	0.46	2.199	14.27	12.049	0.002	0.223	1 < 2
	Mat Pilates ²	19	6.73	11.278	30.18				1<3
	Reformer Pilates ³	14	8.28	13.886	27.75				
Extensor Endurance Test (sec)	Home Exercise ¹	15	0.53	1.597	12.27	17.328	p < 0.001	0.340	1 < 2
	Mat Pilates ²	19	9.84	20.696	28.58				1<3
Kruskal-Wallis Test									
• <i>p</i> < 0.05 significance level									
• Effect sizes were interpreted as follows: for Cohen's <i>d</i> , < 0.20 = small, 0.20–0.79 = moderate, ≥ 0.80 = large; for eta squared (η^2), < 0.01 = small, 0.01–0.13 = moderate, ≥ 0.14 = large; for correlation coefficient (<i>r</i>), < 0.10 = small, 0.10–0.49 = moderate, ≥ 0.50 = large.									
*PFM: pelvic floor muscle; Δ: change (pre–post difference); χ^2 : chi-square; η^2 : eta squared (effect size)									
*Group codes: 1 = Home Exercise, 2 = Mat Pilates, 3 = Reformer Pilates									

Variable	Group	n	Mean	SD	Mean	x ²	p	η ²	Difference
	Reformer Pilates ³	14	17.14	16.204	32.07				
Flexor Endurance Test (sec)	Home Exercise ¹	15	0.20	0.560	12.70	17.869	p < 0.001	0.352	1 < 2
									1<3
	Mat Pilates ²	19	8.68	12.858	26.97				
	Reformer Pilates ³	14	16.85	14.249	33.79				
Hip Endurance Test (sec)	Home Exercise ¹	15	-1.13	3.979	10.33	22.694	p < 0.001	0.459	1 < 2
									1<3
	Mat Pilates ²	19	14.52	18.815	30.82				
	Reformer Pilates ³	14	16.28	17.349	31.11				
Kruskal-Wallis Test									
• p < 0.05 significance level									
• Effect sizes were interpreted as follows: for Cohen's d, < 0.20 = small, 0.20–0.79 = moderate, ≥ 0.80 = large; for eta squared (η ²), < 0.01 = small, 0.01–0.13 = moderate, ≥ 0.14 = large; for correlation coefficient (r), < 0.10 = small, 0.10–0.49 = moderate, ≥ 0.50 = large.									
*PFM: pelvic floor muscle; Δ: change (pre–post difference); χ ² : chi-square; η ² : eta squared (effect size)									
*Group codes: 1 = Home Exercise, 2 = Mat Pilates, 3 = Reformer Pilates									

DISCUSSION

This study, which comparatively evaluated the effects of Mat Pilates, Reformer Pilates, and Home Exercises on pelvic floor muscle strength and endurance, as well as on core and hip muscle endurance, found that both Mat and Reformer Pilates were more effective than the control group in enhancing pelvic floor muscle strength, with Reformer Pilates being the most effective method overall. In terms of core and hip muscle endurance, both Mat and Reformer Pilates were found to be more effective than Home Exercises, although no significant difference was observed between the two. These findings suggest that Reformer Pilates is the most effective method for achieving comprehensive benefits. This superiority may be attributed to distinctive features of Reformer Pilates, such as its mode of application, resistance levels, and proprioceptive stimulation.

The spring-resistance mechanism of Reformer Pilates, along with its multidirectional movement patterns and increased stabilization demands, facilitates more effective activation of target muscle groups. This system supports not only muscle strength development but also enhances motor skills such as proprioceptive awareness, sensorimotor integration, and neuromuscular coordination. Thus, the synchronized activation of deep postural muscles in the pelvic region is facilitated, potentially enhancing kinesthetic control alongside balance reflexes in the individual^{7,18}. Moreover, this method enables sustained and simultaneous activation of the pelvic floor and core muscles, providing high levels of intramuscular stimulation particularly in slow-twitch type I fibers^{8,9}. These effects contribute directly to the enhancement of lumbopelvic stability. However, the literature also presents conflicting findings regarding the impact of Reformer Pilates on pelvic floor muscle strength. In a randomized controlled trial conducted by Parlak et al., the effects of an eight-week Reformer Pilates program on pelvic floor muscle strength and quality of life were evaluated. The study reported only a slight, statistically non-significant increase in muscle strength. Moreover, the group that received Reformer Pilates did not demonstrate a clinically significant advantage over the Mat Pilates group¹⁹. These findings suggest that Reformer Pilates may not elicit the expected physiological response in certain subpopulations and highlight the importance of tailoring exercise programs to individual differences. In our randomized controlled trial, Reformer Pilates was found to be superior to Mat Pilates in enhancing pelvic floor muscle strength in women following a 10-week training period. To maximize the benefits of Reformer Pilates, careful consideration of exercise prescription parameters—such as frequency and duration—may be necessary. Programs lasting at least 10 weeks appear to yield more effective outcomes.

Mat Pilates exercises stand out as an effective method, particularly in enhancing core flexor muscle endurance and hip stability. In our study, significant improvements were observed in these parameters, aligning with findings reported in the existing literature^{20,21}. However, due to its reliance on body weight and lack of external resistance, Mat Pilates may have a more limited impact on pelvic floor muscle function compared to Reformer Pilates²². Nevertheless, due to its safety, low risk, and lack of equipment requirements, it may be preferred as a sustainable exercise option for individuals across different age groups and functional levels²³.

In a study conducted by Lee et al., although a significant increase in abdominal muscle thickness was observed following an eight-week Mat Pilates program, no meaningful improvement was detected in pelvic floor muscle function²⁴. These findings suggest that Mat Pilates may be more effective in targeting superficial and large-volume muscle groups, while its impact on deeper, smaller muscle groups such as the pelvic floor muscles may be limited. However, in our study, Mat Pilates significantly improved the endurance of both pelvic floor and core muscles compared to the control group. In fact, its effect on core and hip muscle endurance is comparable to that of Reformer Pilates; the only difference lies in its relatively lesser impact on the pelvic floor muscles. These findings indicate that either Mat or Reformer Pilates may be selected to enhance the endurance of large, superficial muscles such as those in the abdomen and hips. However, for deeper muscles like the pelvic floor, Reformer Pilates should be the preferred method.

In our study, no significant improvements were observed in the pelvic floor, core, or hip muscle groups within the Home Exercise group. This finding suggests that exercise programs lacking resistance and professional guidance may offer limited physiological benefits. This perspective aligns with existing literature indicating that structured and supervised exercise programs are more effective than individual home-based routines^{25,26}. However, some studies have shown that home-based programs can also be effective when supported by regular follow-up and personalized content. For instance, Khorasani et al. reported that supervised home exercises led to significant improvements in pelvic floor muscle strength and endurance²⁷. These findings suggest that the effectiveness of home exercise programs depends on their being structured, monitored, and reinforced with motivational strategies.

One of the original contributions of this study is the evaluation of pelvic floor muscles not only in traditional supine positions but also in the crunch position accompanied by abdominal activation. While previous literature has examined pelvic floor muscle activity under variations of hip abduction and adduction, perineometric measurements conducted in a crunch position with active core muscle engagement have not been previously reported¹⁴. This method enables the assessment of not only the isolated contraction capacity of the PFM but also its functional performance during core stabilization. The crunch position is clinically significant as it represents real-life scenarios involving increased intra-abdominal pressure, such as coughing, heavy lifting, or breath-holding. The gains observed particularly in the perineometric measurements taken in the crunch and adduction positions indicate that the PFM can respond more effectively to increases in intra-abdominal pressure. This finding holds clinical significance for the support of pelvic organs, urinary continence, and the maintenance of postural stability²⁸. Reformer Pilates, through its resistance-based and supervised approach, can enhance the functional activation of pelvic floor and core muscles, thereby providing a physiological foundation that is both preventive and therapeutic. Accordingly, structured incorporation of Reformer Pilates into clinical practice may be recommended for populations at risk of pelvic dysfunction, such as postpartum women and older adults.

Limitations and Strengths

The methodological limitations of this study include the relatively small sample size, the absence of long-term follow-up data, and the inability to directly monitor individual adherence in the Home Exercise group. Future research could address these limitations by incorporating larger sample sizes and conducting long-term follow-up assessments. However, in our study, the strength and endurance of the pelvic floor and surrounding muscle groups were evaluated in detail. Notably, the analysis of pelvic floor muscles was conducted not only in the supine position but also in the crunch position, which simulates daily activities such as coughing, sneezing, and lifting, thereby offering a more functionally relevant assessment. A key strength of this study is the comparative evaluation of three different Pilates methods using objective measurement tools, which enhances the reliability and clinical relevance of the findings.

Conclusion and Recommendations

In our study, Reformer Pilates emerged as the most effective method for improving pelvic floor muscle strength and endurance, while Mat Pilates demonstrated superiority over home exercises. Mat Pilates was found to be as effective as Reformer Pilates in enhancing core and hip muscle endurance; however, Home Exercises did not yield any clinically significant improvement in muscle endurance. These findings suggest that either Mat or Reformer Pilates may be selected to improve the endurance of large, superficial muscles such

as those in the abdomen and hips. In contrast, for deeper muscles like the pelvic floor, Reformer Pilates should be the method of choice. In clinical practice, the sequential or combined use of these methods based on individual needs may represent a safe and effective approach.

Abbreviations

PFM: Pelvic Floor Muscles

s: Second

cm: Centimeter

kg: Kilogram

kg/m²: Kilogram per square meter

SPSS: Statistical Package for the Social Sciences

BMI: Body Mass Index

n: Sample Size

SD: Standard Deviation

PFMS HLP: Pelvic Floor Muscle Strength in the Hook-Lying Position

PFME HLP: Pelvic Floor Muscle Endurance in the Hook-Lying Position

PFMS HABD: Pelvic Floor Muscle Strength in the Hip Abduction Position

PFMS HADD: Pelvic Floor Muscle Strength in the Hip Adduction Position

PFMS CP: Pelvic Floor Muscle Strength in the Crunch Position

Declarations

Funding: This study received no financial support from any funding agency.

Acknowledgments: The authors have no acknowledgments to declare.

Data Availability Statement: All data generated or analyzed during this study are included in this published article. Further enquiries can be directed to the corresponding author.

Author Contributions:

B.U.T.: Conceptualization, Methodology, Investigation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing, Supervision.

C.D.O.: Conceptualization, Methodology, Investigation, Writing – Review & Editing, Supervision.

O.G.: Conceptualization, Methodology, Investigation, Writing – Original Draft.

I.Y.: Conceptualization, Methodology, Writing – Review & Editing, Supervision.

Ethics Approval and Consent to Participate: Ethical approval for this study was obtained from the relevant institutional ethics committee, and written informed consent was obtained from all participants prior to participation.

Consent for Publication: Not applicable.

Competing Interests: The authors declare no competing interests.

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Figures

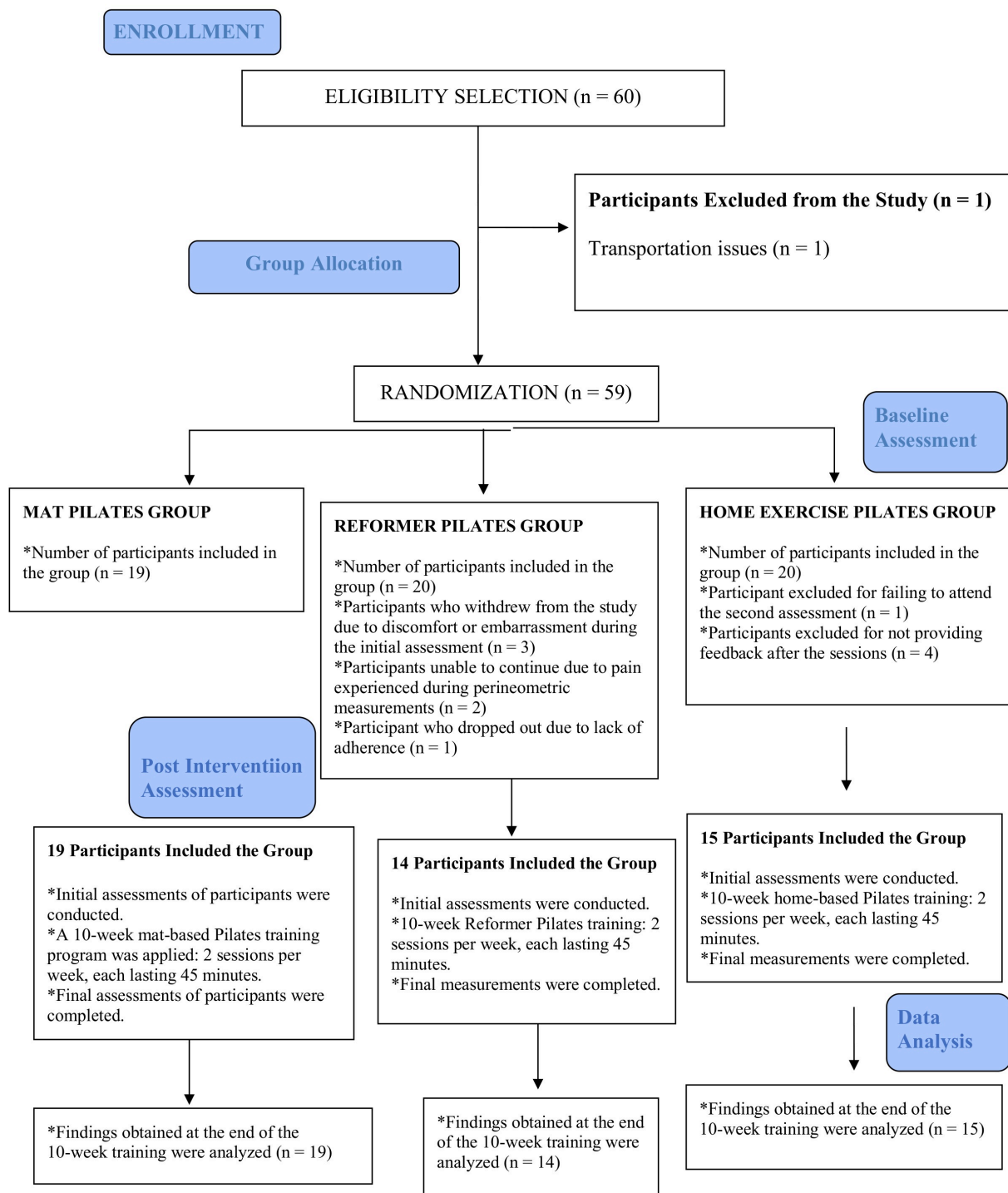


Figure 1

CONSORT Flow Diagram of Participant Enrollment



Figure 2

Pelvic Floor Muscle Strength Assessment Using a Perineometer During Abdominal Muscle Activation

Supplementary Files

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