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Comparative Effects of Biofeedback Electrical Stimulation, Kegel Exercise, and Vaginal Cone Training on Postpartum Pelvic Floor Muscle Weakness in Primiparous Women: A prospective real-world observational study

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Research Article

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Abstract

Purpose

To compare the effects of Kegel exercise (KE), vaginal cone (VC) training, and biofeedback electrical stimulation (BES) on pelvic floor muscle recovery in primiparous women with decreased pelvic floor muscle strength after vaginal delivery.

Patients and methods:

This prospective real-world observational study was conducted at the First Affiliated Hospital of Bengbu Medical University. A total of 2,700 eligible women with decreased pelvic floor muscle strength at 6 weeks postpartum were grouped according to the postpartum pelvic floor rehabilitation treatment they received into the untreated (UT) group, Kegel exercise (KE) group, vaginal cone (VC) group, and bioelectrical stimulation (BES) group. Interventions were administered for 6 weeks. Type I and Type II pelvic floor muscle strength grades were assessed at baseline, 3 months, and 9 months postpartum. Longitudinal changes were analyzed using cumulative link mixed models (CLMMs).

Results

A total of 2,403 participants completed follow-up and were included in the final analysis (UT, n = 608; KE, n = 600; VC, n = 599; BES, n = 596). Baseline characteristics were generally comparable across the four groups. Significant differences in the distributions of Type I and Type II pelvic floor muscle strength grades were observed at both follow-up assessments (all $P < 0.001$). In the CLMM analysis, BES was associated with the greatest and most sustained improvement in both Type I and Type II pelvic floor muscle strength. Compared with the UT group, BES was associated with significantly higher odds of improved Type I muscle strength at 3 months (OR = 3.80, 95% CI: 2.70–5.36) and 9 months (OR = 4.69, 95% CI: 3.34–6.58), and of improved Type II muscle strength at 3 months (OR = 32.44, 95% CI: 22.83–46.09) and 9 months (OR = 4.19, 95% CI: 3.00–5.85). VC training was also associated with significant improvements, whereas KE was associated with more modest and less durable improvements.

Conclusion

BES was associated with the most favorable and sustained recovery of postpartum pelvic floor muscle strength, followed by VC training. KE was associated with comparatively limited improvements. These findings may help inform evidence-based postpartum pelvic floor rehabilitation strategies.

Introduction

Pelvic floor dysfunction (PFD) is a common condition that negatively affects women's quality of life. Pregnancy and vaginal delivery are widely recognized as major risk factors for PFD in young women[1,2]. During pregnancy and childbirth, the pelvic floor muscles (PFMs), connective tissues, and supporting nerves may undergo stretching, compression, and injury, resulting in impaired pelvic floor support and neuromuscular function[3,4]. Consequently, women may experience urinary incontinence, pelvic organ prolapse, sexual dysfunction, and other pelvic floor disorders[5,6].

Among the multiple pathophysiological mechanisms involved in PFD, decreased pelvic floor muscle strength is considered one of the most important and potentially reversible factors[7]. The PFMs provide dynamic support for the bladder, uterus, vagina, and rectum and play a critical role in maintaining continence and pelvic stability[8,9]. In addition, weakened PFMs may adversely affect female sexual function because insufficient muscle contraction and reduced vaginal tone may impair sexual stimulation and arousal[10]. Therefore, restoration of PFM strength during the early postpartum period is regarded as an important target for the prevention and management of postpartum PFD.

Current evidence generally supports conservative rehabilitation as the first-line approach for women with postpartum pelvic floor impairment. Pelvic floor muscle training (PFMT), represented by Kegel exercise (KE), is regarded as the cornerstone of conservative pelvic floor rehabilitation. A Cochrane systematic review demonstrated that PFMT significantly improves urinary incontinence symptoms in women and remains the first-line conservative treatment for pelvic floor disorders[11]. Recent systematic reviews and meta-analyses have further confirmed that PFMT can significantly improve pelvic floor muscle strength and function and remains the foundation of postpartum pelvic floor rehabilitation[12].

Despite its established efficacy, the effectiveness of PFMT depends heavily on correct muscle identification and long-term adherence. Previous studies have suggested that a substantial proportion of women are unable to correctly contract the pelvic floor muscles without professional guidance, potentially limiting the effectiveness of self-directed exercise programs[13]. Consequently, several adjunctive rehabilitation methods have been developed to facilitate pelvic floor muscle activation and improve training outcomes[14].

Vaginal cone (VC) training utilizes weighted intravaginal devices to provide resistance exercise and proprioceptive feedback, thereby facilitating pelvic floor muscle recruitment. A Cochrane review reported that VC training is superior to no active treatment and may achieve outcomes comparable to PFMT in women with urinary incontinence[15]. Subsequent systematic reviews have further suggested that VC training can improve urinary symptoms and pelvic floor muscle performance through repeated resistance-based activation of the pelvic floor muscles[16].

Electrical stimulation has also been widely applied in pelvic floor rehabilitation. By inducing passive muscle contraction and enhancing neuromuscular recruitment, electrical stimulation may be particularly beneficial for women who have difficulty performing effective voluntary contractions[17]. In recent years, biofeedback electrical stimulation (BES), which combines electrical stimulation with real-time feedback of

muscle activity, has become one of the most commonly used rehabilitation modalities. BES allows patients to perceive pelvic floor muscle activity directly, thereby improving muscle awareness, optimizing recruitment patterns, and facilitating motor learning. Previous systematic reviews have demonstrated that biofeedback-assisted PFMT and BES can improve pelvic floor muscle strength, enhance rehabilitation outcomes, and improve quality of life in women with pelvic floor disorders[18,19].

Although PFMT, VC training, and BES have all demonstrated therapeutic benefits, their relative effectiveness remains unclear. Existing studies have mainly focused on symptom-based outcomes such as urinary incontinence and pelvic organ prolapse rather than direct assessment of pelvic floor muscle strength recovery. Furthermore, BES has frequently been evaluated as an adjunctive therapy rather than an independent rehabilitation strategy. Many previous studies investigated PFMT combined with biofeedback or electrical stimulation and reported superior outcomes compared with PFMT alone[20,21]. Consequently, the independent therapeutic contribution of BES remains difficult to determine. Direct comparisons between BES and other commonly used rehabilitation strategies, such as KE and VC training, are relatively scarce, particularly in postpartum populations.

In addition, previous studies often evaluated a single intervention or compared active treatment with routine care, whereas head-to-head comparisons among KE, VC training, and BES remain limited. Moreover, very few studies have separately evaluated Type I and Type II pelvic floor muscle recovery despite their distinct physiological functions. Type I muscle fibers are mainly responsible for sustained contraction and endurance, whereas Type II muscle fibers contribute primarily to rapid contraction and force generation. Finally, long-term follow-up data evaluating the durability of treatment effects remain limited, particularly among postpartum women.

Therefore, the optimal rehabilitation strategy for postpartum women with decreased pelvic floor muscle strength remains uncertain. To address this knowledge gap, we conducted a real-world study comparing KE, VC training, and BES in primiparous women with decreased pelvic floor muscle strength after vaginal delivery. By separately evaluating Type I and Type II pelvic floor muscle strength at baseline, 3 months postpartum, and 9 months postpartum, this study aimed to identify the rehabilitation strategy associated with the most favorable and sustained recovery of postpartum pelvic floor muscle strength.

Material and methods

Study Design and Participants

This real-world study was conducted at the First Affiliated Hospital of Bengbu Medical University, between October 2020 and December 2025. The study was designed to compare the effects of Kegel exercise (KE), vaginal cone (VC) training, and biofeedback electrical stimulation (BES) on pelvic floor muscle recovery in primiparous women with decreased pelvic floor muscle strength after vaginal delivery.

All included patients were grouped according to the postpartum pelvic floor rehabilitation treatment they received into the untreated (UT) group, Kegel exercise (KE) group, vaginal cone (VC) group, and

bioelectrical stimulation (BES) group. Rehabilitation interventions were initiated at 6 weeks postpartum and continued for 6 weeks.

Assessments were performed at three time points: before intervention at 6 weeks postpartum (baseline), immediately after completion of the intervention at 3 months postpartum, and 6 months after completion of the intervention at 9 months postpartum. Participant recruitment, follow-up, and final inclusion are summarized in Fig. 1).

The study protocol was approved by the Ethics Committee of the First Affiliated Hospital of Bengbu Medical University (Approval No. [2023] 480) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment and randomization.

All investigators received standardized training before study initiation to ensure consistency of pelvic floor muscle assessment and intervention delivery across participating centers.

Eligible participants met the following criteria: (1) primiparous women; (2) age 18–35 years; (3) singleton vaginal delivery at 37–40 weeks of gestation; (4) decreased pelvic floor muscle strength at 6 weeks postpartum; and (5) willingness to participate in the study and complete follow-up assessments.

Pelvic floor muscle strength was assessed by trained physicians using a standardized pelvic floor examination system (PHENIX USB4, Vivaltis Medical, France) combined with digital palpation. Type I muscle fiber function was evaluated by sustained maximal voluntary contraction, whereas Type II muscle fiber function was evaluated by repeated rapid contractions. Pelvic floor muscle strength was graded according to the GRRUG classification developed by ANAES. Decreased pelvic floor muscle strength was defined as Type I and/or Type II pelvic floor muscle strength below Grade 3.

Women were excluded if they had pre-existing pelvic floor dysfunction, previous pelvic surgery, pre-pregnancy urinary incontinence, recurrent urinary tract infection, urinary tract malformation, multiple pregnancy, preterm delivery, cesarean delivery, severe obstetric complications, or systemic diseases that could affect pelvic floor function, including diabetes mellitus, connective tissue diseases, neurological disorders, and severe cardiovascular diseases. Women who were unable to complete the required assessments were also excluded.

The primary outcome was recovery of Type I and Type II pelvic floor muscle strength grades at 3 and 9 months postpartum.

Sample size estimation was conducted before participant recruitment. Based on the primary outcome of pelvic floor muscle strength grade distribution among the four study groups, a small effect size (Cohen's $w = 0.10$) was assumed because no previous large-scale head-to-head trial comparing these four rehabilitation strategies was available. Using a two-sided significance level of 0.05 and a statistical power of 90%, at least 608 participants were required in each group. To account for an anticipated dropout rate

of approximately 10%, the planned sample size was increased to 675 participants per group, resulting in a target enrollment of 2,700 participants.

Participants with incomplete follow-up data were excluded from the final analysis.

Pelvic floor muscle strength assessments were performed according to standardized procedures by trained assessors. All investigators received standardized training before study initiation.

Statistical analyses were performed after completion of follow-up using de-identified data. The investigators responsible for statistical analyses were not involved in participant recruitment, intervention delivery, or outcome assessment.

Intervention procedures

All interventions were initiated at 6 weeks postpartum and continued for 6 consecutive weeks. Participants in the KE and VC groups performed home-based training after receiving standardized instruction, whereas BES treatment was administered at hospital by trained physical therapists.

Untreated (UT)

Participants in the UT group received routine postpartum care but did not receive any structured pelvic floor rehabilitation intervention during the study period.

Kegel Exercise (KE)

Participants in the KE group received standardized instruction from trained nurses and performed the prescribed exercises independently at home. They were instructed to perform maximal voluntary pelvic floor muscle contraction for 5 seconds followed by 10 seconds of relaxation. Each session lasted 15 minutes and was performed twice daily, resulting in a total training duration of 30 minutes per day.

Vaginal Cone (VC)

Participants in the VC group received standardized instruction from trained nurses and subsequently performed training independently at home. A standardized 34-g vaginal cone was used for all participants according to the study protocol. The cone was inserted intravaginally, and training was performed in the standing position. Participants were instructed to voluntarily contract the pelvic floor muscles whenever the cone was perceived to be slipping. Each session lasted 15 minutes and was performed twice daily.

Biofeedback Electrical Stimulation (BES)

Participants in the BES group were treated in the supine position with the hips and knees flexed at approximately 45°. Pelvic floor muscle contraction was induced using a PHENIX USB4 pelvic floor rehabilitation system (Vivaltis Medical, France) equipped with an intravaginal electrode. Electrical stimulation was delivered at a frequency of 8–32 Hz and a pulse duration of 320–740 μs. Stimulation intensity was adjusted individually to produce visible pelvic floor muscle contraction without pain or discomfort. Electromyographic biofeedback was displayed in real time to guide voluntary muscle contraction. Each treatment session lasted 25 minutes and was administered twice weekly for 6 weeks by trained physical therapists.

Data Collection

Data were collected at three time points: before intervention at 6 weeks postpartum (baseline), immediately after completion of the 6-week intervention at 3 months postpartum, and 6 months after completion of the intervention at 9 months postpartum.

At baseline, demographic and clinical information was collected, including age, gravidity, birth weight, and study center. Pelvic floor muscle strength assessments were performed at all three study visits. The primary outcome variables were Type I and Type II pelvic floor muscle strength grades.

Pelvic floor muscle strength was assessed by trained physicians using the PHENIX USB4 pelvic floor rehabilitation system (Vivaltis Medical, France) combined with digital palpation. Type I muscle fiber function was evaluated by sustained maximal voluntary contraction, whereas Type II muscle fiber function was evaluated by repeated rapid contractions. Pelvic floor muscle strength was graded according to the GRRUG classification developed by ANAES. Type I and Type II muscle strength grades were recorded separately at each assessment time point.

All data were recorded using standardized case report forms. All investigators received standardized training before study initiation to ensure consistency in pelvic floor muscle assessment and data collection procedures.

Participants with incomplete follow-up or missing pelvic floor muscle strength data were excluded from the final analysis.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA) and R software version 4.4.3 (R Foundation for Statistical Computing, Vienna, Austria).

Continuous variables are presented as mean ± standard deviation (SD), and categorical variables are presented as frequencies and percentages [n (%)]. Baseline continuous variables, including age and birth weight, were compared among the four groups using one-way analysis of variance (ANOVA). Categorical variables, including gravidity, study center, and pelvic floor muscle strength grade distributions, were compared using Pearson’s chi-square test.

Pelvic floor muscle strength grades were treated as ordinal outcomes. Because Type I and Type II pelvic floor muscle strength were repeatedly assessed over time and recorded as ordered categories, cumulative link mixed models (CLMMs) with a logit link function were fitted using the CLMM function from the ordinal package in R. Treatment group, assessment time point, and the group × time interaction were included as fixed effects. Participant ID was included as a random intercept to account for within-subject correlations arising from repeated measurements. The untreated group (UT) and baseline assessment at 6 weeks postpartum were specified as reference categories. Separate models were fitted for Type I and Type II pelvic floor muscle strength.

The main effect of time was used to evaluate overall recovery of pelvic floor muscle strength, whereas the group × time interaction terms were used to determine whether longitudinal changes differed between each rehabilitation group and the UT group. Results are presented as proportional odds ratios (ORs) with 95% confidence intervals (CIs).

Analyses were performed using complete-case data. Participants with incomplete follow-up or missing pelvic floor muscle strength data were excluded from the final analysis. All statistical tests were two-sided, and a P value < 0.05 was considered statistically significant.

Results

Participants

A total of 2,700 primiparous women with decreased pelvic floor muscle strength at 6 weeks postpartum were recruited between October 2020 and December 2025. All participants agreed to participate and provided written informed consent before enrollment. All included patients were grouped according to the postpartum pelvic floor rehabilitation treatment they received into the untreated (UT) group, Kegel exercise (KE) group, vaginal cone (VC) group, and bioelectrical stimulation (BES) group.

During follow-up, 297 participants were lost to follow-up or had incomplete follow-up data, including 67 in the untreated group, 75 in the Kegel exercise group, 76 in the vaginal cone group, and 79 in the biofeedback electrical stimulation group. Finally, 608 participants in the untreated group, 600 in the Kegel exercise group, 599 in the vaginal cone group, and 596 in the biofeedback electrical stimulation group completed the study. A total of 2,403 eligible participants were included in the final analysis.

The baseline demographic and obstetric characteristics of the participants are summarized in Table 1. The mean age of the participants was approximately 26.6 years, and most women had a gravidity of 1. The mean neonatal birth weight was approximately 3,400 g. No significant differences were observed among the four groups with respect to age (P = 0.452), gravidity distribution (P = 0.192), or study center distribution (P = 1.000), indicating good baseline comparability. Although neonatal birth weight differed significantly among groups (P = 0.013), the between-group difference was small (< 60 g) and was considered clinically negligible.

Table 1
Baseline demographic and obstetric characteristics of the participants

Characteristic	UT (n = 608)	KE (n = 600)	VC (n = 599)	BES (n = 596)	P value
Age (years), mean ± SD	26.88 ± 4.45	26.61 ± 4.49	26.49 ± 4.39	26.54 ± 4.61	0.452
Neonatal birth weight(g), mean ± SD	3410.90 ± 314.24	3434.40 ± 316.17	3378.50 ± 305.57	3392.38 ± 316.42	0.013
Gravidity, n (%)					0.192
1	500 (82.2)	510 (85.0)	500 (83.5)	467 (78.4)	
2	101 (16.6)	82 (13.7)	91 (15.2)	116 (19.5)	
3	6 (1.0)	6 (1.0)	7 (1.2)	12 (2.0)	
4	1 (0.2)	2 (0.3)	1 (0.2)	1 (0.2)	

Notes: Data are presented as mean ± SD or n (%). Continuous variables were compared using one-way analysis of variance (ANOVA), and categorical variables were compared using Pearson's chi-square test. P values refer to overall comparisons among the four groups. UT, untreated; KE, Kegel exercise; VC, vaginal cone; BES, biofeedback electrical stimulation; SD, standard deviation.

The baseline distributions of Type I and Type II pelvic floor muscle strength grades are presented in Table 2. No significant differences were observed among the four groups in the distribution of Type I pelvic floor muscle strength grades before intervention (P = 0.824). Similarly, no significant differences were found in the distribution of Type II pelvic floor muscle strength grades among the four groups at baseline (P = 0.723), indicating good comparability of pelvic floor muscle function before treatment.

Table 2
Baseline distributions of type I and type II pelvic floor muscle strength grades among the four groups

Variable	Grade	UT (n = 608)	KE (n = 600)	VC (n = 599)	BES (n = 596)	P value
Type I muscle strength	0	18 (3.0)	24 (4.0)	15 (2.5)	26 (4.4)	
	1	249 (41.0)	241 (40.2)	251 (41.9)	245 (41.1)	
	2	143 (23.5)	135 (22.5)	136 (22.7)	128 (21.5)	
	3	23 (3.8)	18 (3.0)	13 (2.2)	17 (2.9)	
	4	155 (25.5)	166 (27.7)	169 (28.2)	167 (28.0)	
	5	20 (3.3)	16 (2.7)	15 (2.5)	13 (2.2)	0.824
Type II muscle strength	0	15 (2.5)	17 (2.8)	28 (4.7)	22 (3.7)	
	1	253 (41.6)	244 (40.7)	236 (39.4)	241 (40.4)	
	2	133 (21.9)	139 (23.2)	133 (22.2)	138 (23.2)	
	3	15 (2.5)	18 (3.0)	17 (2.8)	17 (2.9)	
	4	175 (28.8)	169 (28.2)	170 (28.4)	154 (25.8)	
	5	17 (2.8)	13 (2.2)	15 (2.5)	24 (4.0)	0.723

Notes: Data are presented as n (%). Pelvic floor muscle strength was graded according to the GRRUG classification developed by ANAES. Type I muscle strength was assessed by sustained maximal voluntary contraction, whereas Type II muscle strength was assessed by repeated rapid contractions. Differences in grade distributions among the four groups were compared using Pearson's chi-square test. UT, untreated; KE, Kegel exercise; VC, vaginal cone; BES, biofeedback electrical stimulation.

Outcome

The distributions of Type I and Type II pelvic floor muscle strength grades at 3 and 9 months postpartum are presented in Table 3. Significant differences in muscle strength grade distributions were observed among the four groups at both follow-up assessments for Type I muscle strength (3 months: $\chi^2 = 140.680$, $P < 0.001$; 9 months: $\chi^2 = 197.186$, $P < 0.001$) and Type II muscle strength (3 months: $\chi^2 = 660.929$, $P < 0.001$; 9 months: $\chi^2 = 205.398$, $P < 0.001$).

Table 3
Distribution of type I and type II pelvic floor muscle strength grades at 3 and 9 months postpartum

	Grade	UT (n = 608)		KE (n = 600)		VC (n = 599)		BES(n = 596)	
		3 months	9 months	3 months	9 months	3 months	9 months	3 months	9 months
Type I	2	103 (16.9)	42 (6.9)	103 (17.2)	32 (5.3)	52 (8.7)	32 (5.3)	0 (0.0)	0 (0.0)
	3	193 (31.7)	351 (57.7)	187 (31.2)	359 (59.8)	177 (29.5)	354 (59.1)	199 (33.4)	200 (33.6)
	4	299 (49.2)	189 (31.1)	294 (49.0)	195 (32.5)	351 (58.6)	195 (32.6)	361 (60.6)	355 (59.6)
	5	13 (2.1)	26 (4.3)	16 (2.7)	14 (2.3)	19 (3.2)	18 (3.0)	36 (6.0)	41 (6.9)
Type II	0	1 (0.2)	—	8 (1.3)	—	4 (0.7)	—	0 (0.0)	—
	1	155 (25.5)	—	86 (14.3)	—	84 (14.0)	—	0 (0.0)	—
	2	201 (33.1)	72 (11.8)	199 (33.2)	59 (9.8)	68 (11.4)	12 (2.0)	0 (0.0)	0 (0.0)
	3	61 (10.0)	311 (51.2)	132 (22.0)	331 (55.2)	79 (13.2)	285 (47.6)	204 (34.2)	225 (37.8)
	4	176 (28.9)	208 (34.2)	158 (26.3)	190 (31.7)	330 (55.1)	290 (48.4)	347 (58.2)	324 (54.4)
	5	14 (2.3)	17 (2.8)	17 (2.8)	20 (3.3)	34 (5.7)	12 (2.0)	45 (7.6)	47 (7.9)

Notes: Data are presented as n (%). Pelvic floor muscle strength was graded according to the GRRUG classification developed by ANAES. Type I muscle strength was assessed by sustained maximal voluntary contraction, whereas Type II muscle strength was assessed by repeated rapid contractions. Group differences in pelvic floor muscle strength grade distributions were assessed using Pearson's χ^2 test. For Type I muscle strength, significant differences were observed among the four groups at both 3 months ($\chi^2 = 140.680$, $P < 0.001$) and 9 months ($\chi^2 = 197.186$, $P < 0.001$). For Type II muscle strength, significant differences were also observed at 3 months ($\chi^2 = 660.929$, $P < 0.001$) and 9 months ($\chi^2 = 205.398$, $P < 0.001$). UT, untreated; KE, Kegel exercise; VC, vaginal cone; BES, biofeedback electrical stimulation.

At 3 months postpartum, participants in the BES and VC groups exhibited a higher proportion of advanced muscle strength grades than those in the KE and UT groups. For Type I muscle strength, Grade 4–5 was observed in 66.6% of women in the BES group and 61.8% in the VC group, compared with 51.7% in the KE group and 51.3% in the UT group. Similarly, for Type II muscle strength, the proportion of women achieving Grade 4–5 was highest in the BES group (65.8%), followed by the VC group (60.8%), whereas substantially lower proportions were observed in the KE group (29.1%) and UT group (31.2%).

At 9 months postpartum, the favorable distribution pattern remained evident. For Type I muscle strength, Grade 4–5 was achieved by 66.5% of participants in the BES group, compared with 35.5%, 34.8%, and 35.6% in the UT, KE, and VC groups, respectively. For Type II muscle strength, Grade 4–5 was observed in 62.3% of women in the BES group and 50.4% in the VC group, whereas the corresponding proportions were 35.0% and 37.0% in the KE and UT groups, respectively.

To further evaluate longitudinal changes in pelvic floor muscle recovery, cumulative link mixed models were fitted with treatment group, assessment time point, and their interaction as fixed effects and participant ID as a random intercept (Table 4). Significant time effects were observed for both Type I and Type II muscle strength. Compared with baseline, the odds of achieving a higher Type I muscle strength grade were significantly increased at both 3 months (OR = 21.34, 95% CI: 16.63–27.40, $P < 0.001$) and 9 months (OR = 17.84, 95% CI: 13.97–22.78, $P < 0.001$). Similarly, significant improvements were observed for Type II muscle strength at both 3 months (OR = 2.14, 95% CI: 1.70–2.69, $P < 0.001$) and 9 months (OR = 14.61, 95% CI: 11.50–18.57, $P < 0.001$).

Table 4
Unadjusted cumulative link mixed model analysis of pelvic floor muscle recovery

Time effects	Effect	OR (95% CI)	P value
Type I muscle strength	3 months vs baseline	21.34 (16.63–27.40)	< 0.001
	9 months vs baseline	17.84 (13.97–22.78)	< 0.001
Type II muscle strength	3 months vs baseline	2.14 (1.70–2.69)	< 0.001
	9 months vs baseline	14.61 (11.50–18.57)	< 0.001
Group × time interaction effects			
Type I muscle strength	BES × 3 months	3.80 (2.70–5.36)	< 0.001
	BES × 9 months	4.69 (3.34–6.58)	< 0.001
	VC × 3 months	1.87 (1.34–2.60)	< 0.001
	VC × 9 months	0.97 (0.70–1.33)	0.838
	KE × 3 months	1.04 (0.75–1.45)	0.808
	KE × 9 months	0.96 (0.70–1.32)	0.803
Type II muscle strength	BES × 3 months	32.44 (22.83–46.09)	< 0.001
	BES × 9 months	4.19 (3.00–5.85)	< 0.001
	VC × 3 months	8.50 (6.03–11.98)	< 0.001
	VC × 9 months	2.00 (1.44–2.77)	< 0.001
	KC × 3 months	1.61 (1.17–2.23)	0.004
	KC × 9 months	1.05 (0.77–1.44)	0.754

Notes: ORs represent proportional odds ratios estimated from cumulative link mixed models with a logit link function. Models included treatment group, assessment time point, and the group × time interaction as fixed effects, with participant ID included as a random intercept. The UT group and baseline assessment (6 weeks postpartum) were used as reference categories. Separate models were fitted for Type I and Type II pelvic floor muscle strength. UT, untreated; KE, Kegel exercise; VC, vaginal cone; BES, biofeedback electrical stimulation; OR, odds ratio; CI, confidence interval.

For Type I muscle strength, compared with the UT group, the BES group demonstrated significantly greater improvement at both 3 months (OR = 3.80, 95% CI: 2.70–5.36, P < 0.001) and 9 months (OR = 4.69, 95% CI: 3.34–6.58, P < 0.001). The VC group also showed significantly greater improvement at 3 months (OR = 1.87, 95% CI: 1.34–2.60, P < 0.001), whereas the difference was no longer significant at 9 months (OR = 0.97, 95% CI: 0.70–1.33, P = 0.838). No significant differences were observed between the KE and UT groups at either follow-up assessment (all P > 0.05).

For Type II muscle strength, the BES group demonstrated significantly greater recovery than the UT group at both 3 months (OR = 32.44, 95% CI: 22.83–46.09, P < 0.001) and 9 months (OR = 4.19, 95% CI: 3.00–5.85, P < 0.001). The VC group also showed significantly greater improvement at 3 months (OR = 8.50, 95% CI: 6.03–11.98, P < 0.001) and 9 months (OR = 2.00, 95% CI: 1.44–2.77, P < 0.001). Although the KE group demonstrated a modest improvement at 3 months (OR = 1.61, 95% CI: 1.17–2.23, P = 0.004), this effect was not maintained at 9 months (OR = 1.05, 95% CI: 0.77–1.44, P = 0.754).

Overall, both the distribution analysis and CLMM results consistently indicated that BES was associated with the greatest and most sustained improvement in pelvic floor muscle strength, followed by VC training. Improvements associated with KE were modest and were not sustained during long-term follow-up.

Discussion

In this prospective real-world observational study, we compared the effects of Kegel exercise (KE), vaginal cone (VC) training, and biofeedback electrical stimulation (BES) on postpartum pelvic floor muscle recovery in primiparous women with decreased pelvic floor muscle strength after vaginal delivery. The principal findings of this study were that all three rehabilitation strategies promoted pelvic floor muscle recovery to varying degrees compared with no treatment, whereas BES was associated with the most favorable and sustained improvement in both Type I and Type II pelvic floor muscle strength. VC training also demonstrated significant benefits, while KE produced comparatively modest improvements. Collectively, these findings suggest that rehabilitation strategies incorporating device-assisted muscle activation and real-time feedback may provide greater recovery of postpartum pelvic floor muscle strength than self-directed exercise alone.

To improve the reliability of pelvic floor muscle assessment, both digital palpation and intravaginal electromyographic evaluation were used in the present study. Pelvic floor muscle strength was graded according to the GRRUG classification of ANAES, which remains one of the most widely used clinical assessment systems. Compared with the no-treatment group, all active interventions improved pelvic floor muscle strength after treatment. However, the magnitude of improvement differed among the rehabilitation strategies. Participants receiving BES achieved higher recovery grades and consistently demonstrated more favorable outcomes in the CLMM analysis. These findings suggest that BES was associated with the most favorable recovery of pelvic floor muscle strength among the three rehabilitation strategies evaluated.

The association between BES and improved pelvic floor muscle recovery is biologically plausible. Electrical stimulation can directly activate pelvic floor muscles and associated neural pathways[22], facilitating muscle recruitment even in women who are unable to perform effective voluntary contractions. In addition, biofeedback provides real-time information regarding muscle activity, allowing patients to identify correct contraction patterns and improve neuromuscular coordination. The combination of passive muscle activation and active motor learning may contribute to the favorable outcomes observed in the BES group. Previous systematic reviews have similarly reported that biofeedback-assisted pelvic

floor rehabilitation can improve pelvic floor muscle strength and enhance rehabilitation outcomes in women with pelvic floor disorders[23].

An important feature of the present study is that BES was evaluated as an independent rehabilitation strategy rather than solely as an adjunct to pelvic floor muscle training. In many previous studies, electrical stimulation and biofeedback were incorporated into conventional pelvic floor muscle training programs, and favorable outcomes were frequently reported with these combined approaches. However, evidence directly evaluating BES as a standalone intervention remains relatively limited, particularly in postpartum populations. Consequently, the relative effectiveness of BES compared with other commonly used rehabilitation strategies has not been fully established. The findings of the present study provide additional evidence supporting the effectiveness of BES as an independent postpartum rehabilitation strategy.

An additional consideration is that the three rehabilitation strategies differed not only in treatment modality but also in the degree of professional supervision and feedback provided. Participants receiving BES attended regular clinic-based sessions under professional guidance and received real-time feedback regarding muscle activity, whereas KE and VC training were largely performed at home. Consequently, the superior outcomes observed in the BES group may reflect not only the physiological effects of electrical stimulation and biofeedback but also the benefits of structured supervision, improved adherence, and immediate correction of contraction techniques. Future studies using factorial designs or standardized supervision protocols may help distinguish the independent contributions of treatment modality and professional guidance to postpartum pelvic floor muscle recovery.

VC training represented the second most favorable intervention in our study. Compared with no treatment, VC training was associated with significant improvements in both Type I and Type II pelvic floor muscle strength and maintained favorable outcomes during follow-up. These findings are consistent with previous evidence suggesting that vaginal cones improve pelvic floor muscle performance through resistance-based exercise and proprioceptive feedback. Retaining a weighted cone within the vagina requires repeated activation of the pelvic floor muscles, thereby strengthening muscle contraction and enhancing motor control[24]. The sustained benefits observed in the VC group suggest that resistance-based pelvic floor training may be an effective strategy for postpartum muscle recovery.

Although KE remains the most widely recommended first-line conservative rehabilitation strategy, its effects were less pronounced than those observed with BES and VC training in the present study. This finding should be interpreted cautiously. In our study, KE was performed as a home-based self-directed exercise program without direct supervision, real-time feedback, or objective monitoring of adherence. Previous studies have shown that a substantial proportion of women are unable to correctly identify and contract the pelvic floor muscles without professional guidance, which may substantially reduce the effectiveness of pelvic floor muscle training. Furthermore, exercise adherence was not formally assessed in the present study, making it difficult to distinguish whether the relatively modest outcomes observed in the KE group were attributable to limited efficacy of the intervention itself or to suboptimal adherence and exercise performance. Therefore, our findings may suggest that unsupervised home-based KE provides

limited benefit for postpartum pelvic floor muscle recovery, rather than indicating that pelvic floor muscle training is ineffective as a rehabilitation strategy.

Another notable finding was the differential recovery pattern of Type I and Type II pelvic floor muscle fibers. Type I muscle fibers are primarily responsible for sustained contraction and endurance, whereas Type II muscle fibers contribute mainly to rapid contraction and force generation. Because both fiber types play distinct physiological roles in maintaining pelvic floor support and continence function, separate evaluation provides a more comprehensive assessment of postpartum muscle recovery. Improvement in Type I muscle strength may enhance the ability of the pelvic floor to provide long-term support for pelvic organs, whereas recovery of Type II muscle strength may improve rapid responses to sudden increases in intra-abdominal pressure, such as coughing, sneezing, or physical exertion[25,26]. Relatively few previous studies have independently evaluated Type I and Type II muscle recovery. The present study therefore provides additional evidence regarding the fiber-specific effects of different rehabilitation strategies and highlights the importance of assessing multiple dimensions of pelvic floor muscle recovery.

The strengths of this study include its large sample size and long-term follow-up. Furthermore, both Type I and Type II pelvic floor muscle strength were evaluated separately, allowing a more detailed assessment of rehabilitation outcomes than has been reported in many previous studies.

Several limitations should be acknowledged. First, because of the nature of the interventions, participant and therapist blinding was not feasible. Second, although both digital palpation and electromyographic assessment were used, no universally accepted gold standard currently exists for evaluating pelvic floor muscle function, and measurement variability between assessors cannot be completely excluded and inter-rater reliability was not formally evaluated which may have contributed to residual measurement error. Third, KE and VC training required active participation outside the clinical setting, and actual adherence and exercise quality could not be objectively monitored, potentially resulting in underestimation of their treatment effects. Fourth, although neonatal birth weight differed statistically among groups at baseline, the absolute difference in mean birth weight was less than 60 g and is unlikely to be clinically meaningful. Finally, although follow-up was performed until 9 months postpartum, longer-term studies are needed to determine whether the observed differences among rehabilitation strategies persist over time. Sixth, several limitations inherent to the prospective real-world observational study should be acknowledged. Because treatment allocation was not randomized and was determined by routine clinical practice, patient preference, and clinical decision-making, baseline differences among the untreated, Kegel exercise, vaginal cone, and biofeedback electrical stimulation groups may have introduced selection bias and confounding by indication. Such confounding from unmeasured or inadequately measured factors, such as treatment motivation, adherence, socioeconomic status, and symptom severity, cannot be excluded. In addition, variations in treatment implementation and compliance under real-world conditions may have increased between-patient heterogeneity. Therefore, the observed associations should not be interpreted as definitive evidence of causal treatment effects. Nevertheless, the prospective collection of data in routine clinical settings enhances the clinical relevance and external validity of the findings.

In conclusion, BES was associated with the most favorable recovery of postpartum pelvic floor muscle strength, followed by VC training, whereas KE was associated with comparatively modest improvements. These findings provide additional evidence regarding the relative effectiveness of commonly used postpartum rehabilitation strategies and may help inform clinical decision-making for women with decreased pelvic floor muscle strength after childbirth.

Conclusion

In this prospective real-world observational study, biofeedback electrical stimulation (BES) was associated with the greatest and most sustained improvement in postpartum pelvic floor muscle strength. Vaginal cone (VC) training also demonstrated beneficial effects, particularly during the early postpartum period, whereas the effects of Kegel exercise (KE) were relatively modest and were not consistently maintained during follow-up. By directly comparing these commonly used rehabilitation strategies and separately evaluating Type I and Type II pelvic floor muscle recovery, this study provides evidence regarding their relative effectiveness in postpartum women with decreased pelvic floor muscle strength. These findings support BES as the most effective rehabilitation strategy among the interventions evaluated and may help guide evidence-based postpartum pelvic floor rehabilitation. Further studies with longer follow-up are needed to determine the long-term durability of treatment effects and their impact on pelvic floor dysfunction-related symptoms and quality of life.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of the First Affiliated Hospital of Bengbu Medical University (Approval No. [2023] 480). Written informed consent was obtained from all participants before enrollment. All procedures were conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Availability of data and materials

The datasets generated and analyzed during the current study are available from the first author, Chao Wang, upon reasonable request and subject to approval by the corresponding author and the affiliated

institution.

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Authors' information

Not applicable.

Authors' contributions

C.W. and Z.B. wrote the main manuscript text, and C.S. performed the statistical analyses and prepared tables and figures. C.W and G.Y. conceived of the study. G.Y. participated in the study design. G.Y. supervised this work. All authors read and approved the final manuscript. All scientific content, data interpretation, and conclusions were developed and verified by the authors, who take full responsibility for the final manuscript.

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Figures

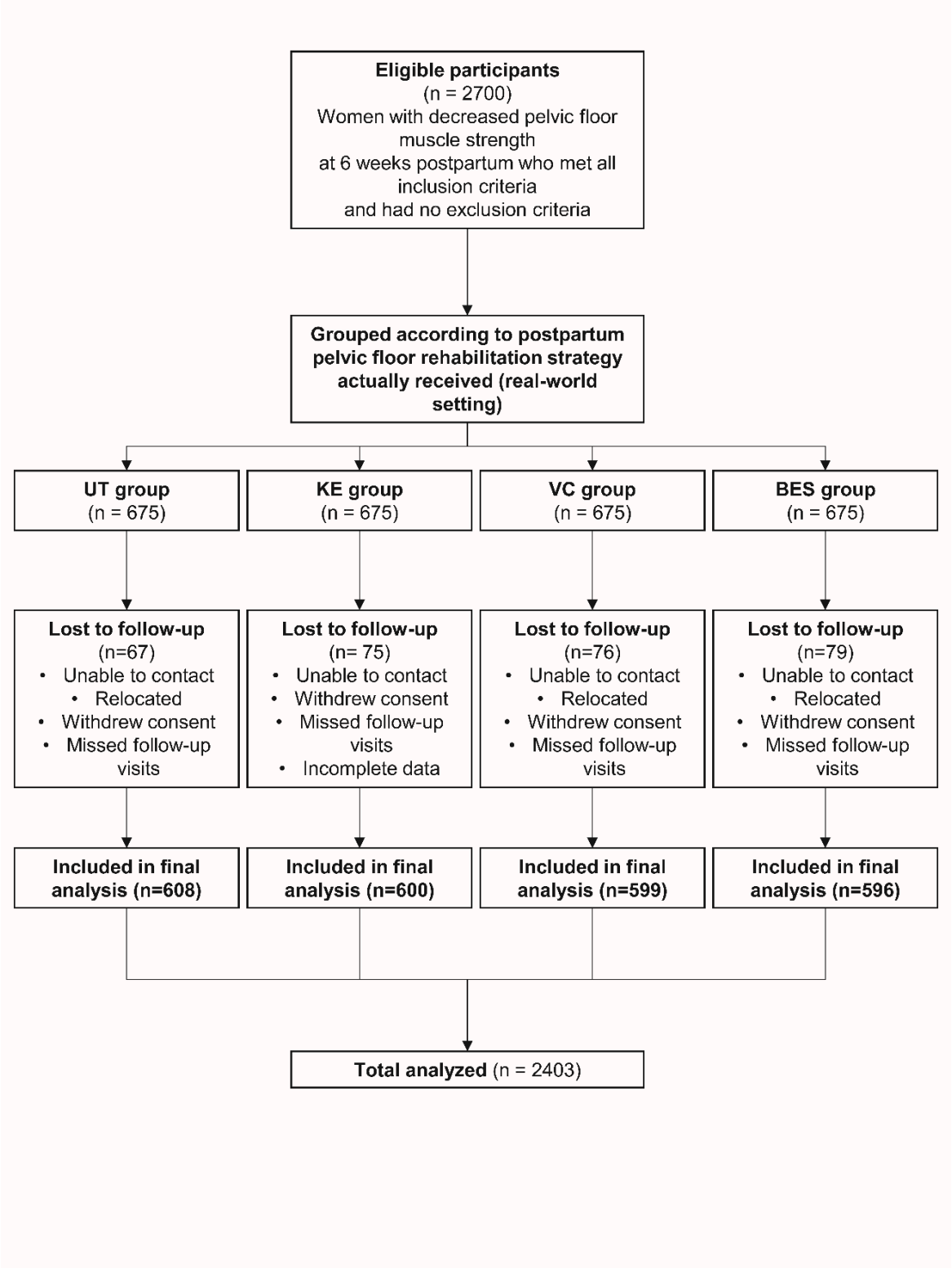


Figure 1

Study flow diagram