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ORIGINAL RESEARCH ARTICLE

Two year follow-up and comparison of pelvic floor muscle electromyography after first vaginal delivery with and without episiotomy and its correlation with urinary incontinence: A prospective cohort study

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Abstract

Introduction: Few prospective studies have revealed the long-term neuromuscular alterations of pelvic floor after vaginal delivery. The aim of this study was to evaluate the impact of episiotomy on the electrical activity of pelvic floor muscle 2 years following vaginal delivery, and explore the relation between surface electromyography (sEMG) amplitudes and urinary incontinence.

Material and methods: A total of 427 primiparous women with full-term singleton vaginal delivery were included in the cohort and 362 with no further births within the 2 year follow-up completed observations. Of these, 200 underwent episiotomy and 162 underwent nonepisiotomy. Clinical demographic characteristics, vaginal EMG variables and urinary incontinence-specific questionnaire scores were collected at 6 weeks, 6, 12 and 24 months after childbirth, respectively. Primary outcomes were the comparison of sEMG values between the episiotomy and nonepisiotomy groups throughout 2 years. Secondary outcomes were the correlation between sEMG of both

Abbreviations: IIQ-7, Impact Questionnaire Short Form; MTC, five 10-s endurance contractions alternated with 10-s rests to measure average mean amplitude (μV); PFM, Pelvic floor muscle; POSTBR, Average mean amplitude of post-baseline rest; pp12m, 12 months postpartum; pp24m, 24 months postpartum; pp6m, 6 months postpartum; pp6w, 6 weeks postpartum; PPC, five maximal fast contractions with 10-s rests in between to measure average peak amplitude (μV); PREBR, Average mean amplitude of prebaseline rest; sEMG, Surface electromyography; UI, Urinary incontinence.

groups and the incidence and severity of urinary incontinence. Spearman's correlation analysis, Kruskal-Wallis test and ANOVA with Bonferroni correction were used to analyze the variables.

Results: Amplitude of maximal fast and endurance contractions on sEMG in the episiotomy group was significantly lower than the nonepisiotomy counterpart. Such difference of sEMG persisted for a long period after birth: endurance contraction, 33.12 ± 8.92 vs 35.085 ± 9.98, $p < 0.01$ at 24 months, and fast contraction, 36.53 ± 8.87 vs 39.05 ± 9.98, $p = 0.01$ at 12-month. Although there was no significant difference in incidence and severity of urinary incontinence between both groups, a negative correlation existed between EMG values of muscle contraction and urinary incontinence symptoms throughout.

Conclusions: Primiparous women delivered with episiotomy demonstrated lower contractile sEMG activity of pelvic floor muscle in the long term. The lower sEMG values of fast contraction were associated with urinary incontinence symptoms.

KEYWORDS
electromyography, episiotomy, pelvic floor muscle, postpartum, urinary incontinence

1 | INTRODUCTION

Pelvic floor disorders, including urinary incontinence (UI), pelvic organ prolapse, fecal incontinence and sexual dysfunction, are associated with weakening of the pelvic floor muscles (PFMs) and are prevalent health problems that affect women's physical and mental health.[1,2] Vaginal delivery, especially those with episiotomy, may contribute to impaired PFM force and endurance by injuring and denervating PFM.[2–4]

Evaluation of PFM is the fundamental step for further intervention against UI. No gold standard method for PFM evaluation has been established up to now. A variety of methods, including vaginal palpation, manometry, dynamometry, surface electromyography (sEMG), ultrasonography, and magnetic resonance imaging,[5] are used to estimate PFM function. Vaginal sEMG is relatively objective by comparison, and is also noninvasive and painless.[6,7] EMG amplitude represents the electrical activation and the recruitment of the motor units following neurostimulation.[7,8] Surface EMG records electrical signals generated by the depolarization of muscle fibers and reflects the muscle force by the degree of activation: the higher the sEMG level, the larger the force generated by the muscle.[7–9] Few studies have been conducted on how vaginal delivery impact pelvic floor electromyography.[6,10] Recent studies[6,10] have shown that vaginal delivery is associated with low EMG level of PFM contractions in early postpartum. However, the longer-term influence of childbirth, especially with respect to episiotomy, on PFM electrophysiology is still unclear, and neither is the correlation between EMG amplitudes and postpartum UI symptoms.

In this study, we established a cohort of 427 postpartum women and evaluated how vaginal delivery impact the PFM electrophysiological activity after childbirth, through comparison of sEMG parameters between episiotomy and nonepisiotomy groups at different time points spanning a two-year period. We investigated the relation between EMG values in both groups and the incidence and severity of UI symptoms.

Key message

Vaginal delivery, especially episiotomy, plays a long-term negative role on pelvic floor muscles contractile electromyography, which has a negative correlation with urinary incontinence complaints.

2 | MATERIAL AND METHODS

2.1 | Study population and data source

The current study was a single-center longitudinal prospective cohort study. Recruitment, exposure, follow-up and data collection were all conducted in hospital settings at Beijing Hospital, a tertiary-level unit in Beijing, China, from September 2016 to December 2018. Electronic medical records were referred for eligibility screening, group allocation and baseline analysis. Eligible women were recruited consecutively from September to December 2016, during their postnatal consultations 6 weeks after childbirth. Participants underwent routine follow-ups of PFM electromyography and UI questionnaire assessments until 24 months after delivery. All participants signed an electronic informed consent form before filling out the questionnaire for the first time at 6 weeks postpartum.

To eliminate possible confounders, inclusion and exclusion criteria were established according to previous multivariate analyses.[4,11] Specifically, the inclusion criteria were as follows: (1) Primipara with singleton pregnancy, (2) over 18 years of age, (3) full-term pregnancy with vaginal delivery over 37 complete week gestation, (4) absence of serious medical complications in both mother and baby, and (5) absence of UI symptoms pre-pregnancy. The exclusion criteria were as follows: (1) Previous miscarriage after gestational week 16, (2) history of pelvic floor surgery, (3) instrumented delivery, (4) third/fourth degree perineal tears, (5) greater than stage III in pelvic organ prolapse quantification system (POP-Q) (the most distal portion of the prolapse protrudes more than 1 cm below the hymen), (6) new pregnancy during the observation period, (7) incorrect PFM contraction with excessive activation of abdominal muscles (>10 μV) or hip adductors, and (8) participation in rehabilitation intervention, including PFM training, with or without electrical stimulation and biofeedback.

2.2 | Definition of exposure and outcomes

Eligible women were dichotomized into the episiotomy and non-episiotomy groups according to their electronic medical records. Only selective mediolateral episiotomy was performed in this study. Baseline obstetric data of each participant were also obtained from the medical records. Among these data, we defined some to be potential confounders and compared them between groups, including age, education level, body mass index, weight gain during pregnancy, length of the first or second stage, birthweight and head circumference of the fetus. Body mass index was calculated (kg/m^2) by weight and height. The first stage of labor is the interval between the onset of labor and full cervical dilatation. The second stage is the interval between full cervical dilatation and the fetal delivery. Both groups were offered four face-to-face appointments with a physiotherapist, at week 6, month 6, 12 and 24 postpartum, respectively (Figure 1). During each visit, the therapist examined the participants, performed intravaginal electromyography measurement and gave technical support when they filled out the Impact Questionnaire Short Form (IIQ-7) questionnaire. Primary outcomes were the comparison of sEMG values between the episiotomy and nonepisiotomy groups over 2 years. Secondary outcomes were the correlation between sEMG values of both groups and the incidence and severity of UI indicated by IIQ-7 questionnaire.[12,13]

2.2.1 | Assessment of PFMs with EMG

The sEMG signals were detected using the "MLD V2 Vaginal Electrode" intravaginal electrodes (Medlander Medical Technology Inc.). Data of the signals were collected at 16-bit resolution at a sampling frequency of 8192 Hz, using the two-channel sEMG device, Biological Feedback and Stimulation System (Model B2S, Medlander Medical Technology Inc.) with the following parameters: channel A for PFM signals and channel B for signals from rectus abdominis. The sEMG data were processed using Biostim software (Medlander Medical Technology Inc.).

The intrapelvic PFM sEMG was assessed according to the Glazer protocol.[14,15] Briefly, the participant was in a supine position with the upper body at an approximately 120-degree angle to the lower half body. The legs were externally rotated with knees slightly

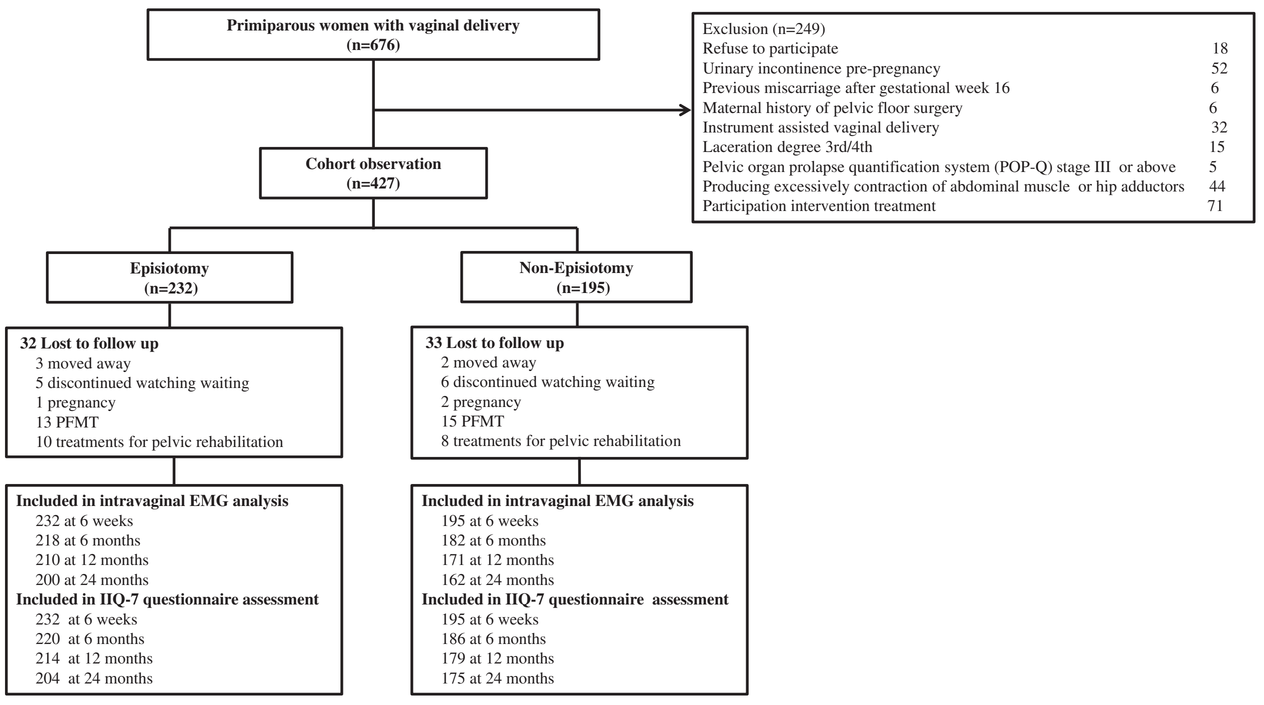

FIGURE 1 Flow chart of participants through study.

separated. The whole body was in a fully relaxed state, and a soft pillow was placed under the knees. The pear-shaped MLD V2 probe with a longitudinal stainless electrode on either side was inserted up to the thinnest part of probe, at the level of the introitus (Figure 2). The electrodes were positioned at the lateral vaginal walls. Two 45 by 45 mm self-adhesive electrodes were placed on either side of the rectus abdominis with the upper margin of the pad parallel to the umbilicus (2 cm outside the umbilicus), and the other abdominal electrode pad was aligned upwards and placed 2 cm below it. Reference electrodes for channel A and channel B were both placed on the anterior superior iliac spine. Before practicing the protocol, the patient was educated on how to isolate the abdominal, gluteal, or adductor muscles and the participants understood that the contraction of these muscles would affect the sEMG data of PFMs. Then, the patient was trained to differentiate contractions by practicing maximal fast contractions and 5–10 s endurance contractions. After 10 min of rest in the supine position, the EMG test started, during which the patient was expected to perform a series of PFM contraction strictly according to voice prompts. The protocol consisted of four steps (Figure 2) (1) 60-s prebaseline rest to measure average mean amplitude (μV) (PREBR), (2) five maximal fast contractions with 10-s rests in between to measure average peak amplitude (μV) (PPC), where participants were instructed to contract the PFM as quickly as possible and to relax the PFM immediately after each contraction, (3) five 10-s endurance contractions alternated with 10-s rests to measure average mean amplitude (μV) (MTC), and (4) 60-s post-baseline rest to measure average mean amplitude (μV) (POSTBR). During the PFM contractions, minimal activation of the abdominal, gluteal, or adductor muscles was required. Throughout the study all testing procedures were conducted by one physiotherapist familiar with the operation process.

2.2.2 | Assessment of pelvic floor dysfunction with UI impact questionnaire short form (IIQ-7)

The IIQ-7 is a UI-specific questionnaire used to assess UI symptoms and evaluate the frequency, severity and impact on the quality of life. The form contains seven items scored on a four-point scale, covering physical activity, emotional health, travel, and social activity. The score ranges from 0 to 100, with higher scores indicating more severe symptoms and lower quality of life.[16] The IIQ-7 is a condensed form of the original IIQ, whose result is strongly correlated with that of the original IIQ ($r = 0.97$).[13,16] The IIQ-7 exhibits high validity, reliability, and sensitivity with a test–retest score of 84%.[12] Prior to this study, IIQ-7 had been translated into Chinese and validated in China.[13]

In this study, an IIQ-7 scoring of/above zero indicated the absence/presence of UI; incidence of UI was calculated by the occurrence ratio of IIQ-7 scores above zero,[16] and severity of UI was determined by IIQ-7 scores, with higher IIQ-7 score indicated higher UI severity.[16]

2.3 | Statistical analyses

The mean and standard deviation of sEMG amplitudes were calculated using data collected from 100 randomized participants per group (episiotomy vs nonepisiotomy) at 6-weeks postpartum before this study. We assumed an alpha (α) risk of 5% and a beta (β) risk of 20% (a power of 80%). With these criteria, our study required at least 152 women in each group; therefore, we planned to include 190 women in both groups, allowing for a drop-out rate of 20% (Table S1). Multiple regression analyses were performed to compare baseline differences between the two groups.

In this study, the sEMG amplitudes (PPC, MTC, PREBR and POSTBR) and UI outcomes (incidence and severity based on IIQ-7 score) were compared intergroup (episiotomy vs nonepisiotomy), and intragroup (6 weeks postpartum [pp6w], 6 months postpartum [pp6m], 12 months postpartum [pp12m] and 24 months postpartum [pp24m]), respectively within the two-year time frame. Statistical analysis was performed using IBM SPSS software version 22.0 (SPSS Inc.). The data with normal distribution is expressed by $\bar{x} \pm s$ and the Student's t-test was used for comparison; otherwise, it is expressed by the number of cases or percentages (%) and the Mann–Whitney U test was used for comparison. Spearman's correlation analysis

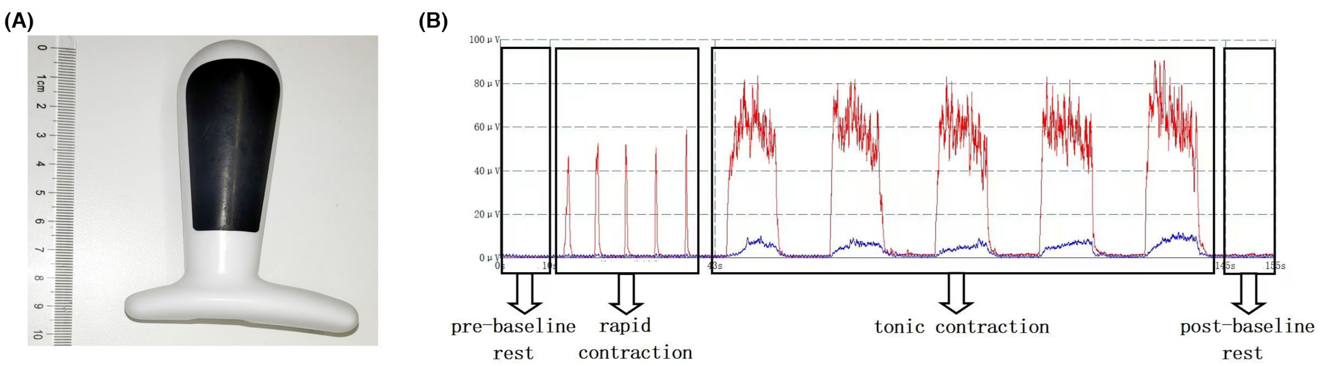

FIGURE 2 Surface electromyography assessment in this study. (A) A pear-shaped intravaginal sensor probe with two electrodes used for recording electromyography signals; (B) Four segments assessed: prebaseline rest, phasic contractions, tonic contractions, and post-baseline rest on electromyography.

was used to test for correlation between sEMG data and quality of life outcomes of UI. Correlation values were interpreted according to the following guidelines: 0.00 to 0.19 = none to slight; 0.2 to 0.39 = slight; 0.40 to 0.69 = moderate; 0.70 to 0.89 = high; and 0.90 to 1.00 = very high.[17] As four comparisons were performed between two groups at different time points, we applied Bonferroni correction to adjust the α level to control for the probability of committing a type 1 error. The comparison of baseline demographic and obstetrics data between groups with $p < 0.05$ was considered statistically significance. However, a two-sided p-value <0.0125 was considered to indicate statistical significance in the comparisons of two groups at different timepoints and in the correlation analysis between EMG amplitudes and UI outcomes.

2.4 | Ethics statement

The study was approved by the Beijing Hospital Medical Ethics Committee (2019BJYYEC-014-02) on February 15, 2019 and has been registered at www.chictr.org.cn (ChiCTR19000 21717).

3 | RESULTS

A total of 676 women were invited into this study initially during postnatal consultations and after eligibility screening, 427 women were enrolled with signed informed consent between September 2016 and December 2016; 232 in the episiotomy group and 195 in the nonepisiotomy group. At follow-up stage, people dropped out for miscellaneous reasons. Among them, some participants became ineligible halfway for pregnancy or receiving interventions, some failed to respond for appointments and opted out, some moved or changed contact information and lost touch, and a few others withdrew for unknown reasons. For whatever reason, data with key outcomes (sEMG and IIQ-7 score) missing at any timepoint within the two-year observation were eliminated from our final analysis. Of note, neither the total attrition rate nor the number of withdrawals attributed to each reason were found to differ remarkably between the episiotomy and the nonepisiotomy groups. By December 2018, 362 (362/427, 84.78%) had completed all appointments during 24 months postpartum, 200 (200/232, 86.21%) in the episiotomy group and 162 (162/195, 83.08%) in the nonepisiotomy group, as shown in Figure 1. Baseline demographic and clinical characteristics are outlined in Table 1, and there was no significant difference between the two groups at baseline (Table 1). For this reason, we did not conduct confounder-adjusted estimation in this study.

Surface EMG amplitudes of two groups were statistically different in terms of fast and endurance contractions (Figure 3, Table S2). On the one hand, the episiotomy group produced consistently lower sEMG amplitudes of fast contraction than the nonepisiotomy group until 12 months after delivery (episiotomy vs. nonepisiotomy: baseline 19.93 ± 6.16 vs 23.97 ± 7.10, pp6m 28.53 ± 8.41 vs 34.14 ± 8.44, pp12m 36.32 ± 8.87 vs 39.05 ± 9.98 μV, all $p < 0.01$). Meanwhile, lower EMG of endurance contraction persisted among women with episiotomy until 24 months postpartum (episiotomy vs nonepisiotomy: baseline 12.48 ± 5.79 vs 16.17 ± 6.83, pp6m 21.47 ± 6.94 vs 24.89 ± 7.05, pp12m 28.52 ± 8.12 vs 32.05 ± 6.97, pp24m 33.12 ± 8.92 vs 35.80 ± 7.62 μV, all $p < 0.01$). On the other hand, sEMG amplitudes increased drastically with time in both the episiotomy and nonepisiotomy groups (Figure 3, Table S2). Both in fast and endurance contraction, significant difference in sEMG amplitudes existed between every two adjacent assessments in two groups. However, there was no significant difference in electromyography of both pre- and post-baseline rest either between, or within, the two groups ($p > 0.05$).

Women in the episiotomy group exhibited higher UI incidence than those in the nonepisiotomy group at pp6w (39 [19.50%] vs 18

TABLE 1 Demographic and obstetric variables of participants

Variables	Total (n = 362)	Nonepisiotomy (n = 162)	Episiotomy (n = 200)	t/χ^2 value	p-value
Age (y)	30.37 ± 3.19	30.34 ± 3.05	30.40 ± 3.30	−0.16	0.87
Education level (n [%])				0.51	0.48
College or university	343 (94.8)	155 (95.7)	188 (94.0)		
Primary-, high school, or other	19 (5.25)	7 (4.32)	12 (6.00)		
BMI pre-pregnancy (kg/m^2)	21.08 ± 3.32	20.91 ± 2.92	21.22 ± 3.61	−0.9	0.37
BMI at labor (kg/m^2)	26.44 ± 3.60	26.47 ± 3.23	26.40 ± 3.87	0.17	0.87
Weight gain during pregnancy (kg)	14.34 ± 5.12	14.91 ± 5.05	13.89 ± 5.13	1.89	0.06
Length of second stage (h)	0.68 ± 0.42	0.66 ± 0.42	0.70 ± 0.42	−0.94	0.35
Length of first stage (h)	6.06 ± 2.23	5.81 ± 2.27	6.26 ± 2.18	−1.9	0.06
Infant birthweight (g)	3271.44 ± 433.89	3227.41 ± 408.71	3307.11 ± 451.13	−1.74	0.08
Infant head circumference (cm)	32.86 ± 1.16	32.76 ± 1.02	32.93 ± 1.26	−1.46	0.144

Note: Data are presented as mean with SDs or numbers with percentages; p-value <0.05 was considered statistically significant.
Abbreviations: BMI, body mass index.

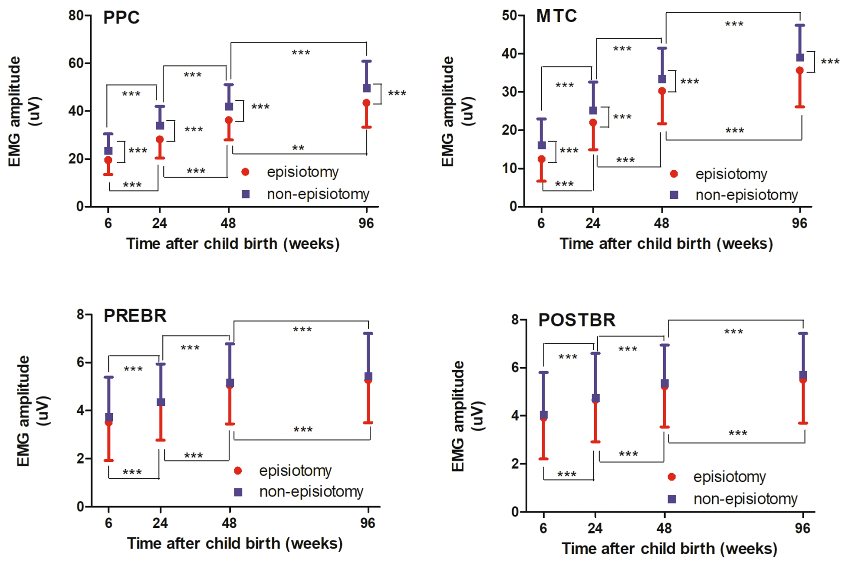

FIGURE 3 Electromyography (EMG) variables at four checkups between women who delivered with and without episiotomy. PPC, five maximal fast contractions with 10-s rests in between to measure average peak amplitude (μV); MTC, five 10-s endurance contractions alternated with 10-s rests to measure average mean amplitude (μV); PREBR, average mean amplitude of prebaseline rest; POSTBR, average mean amplitude of post-baseline rest.

[11.11%], $p = 0.03$) and pp6m (26 [13.00%] vs 9 [6.17%], $p = 0.04$). As for UI severity, women in the episiotomy group demonstrated higher IIQ-7 scores (Table 2) in pp6m ([18.62 ± 13.75] vs [11.11 ± 5.83], $p = 0.03$) and pp12m ([14.29 ± 7.10] vs [7.93 ± 2.46], $p = 0.02$). Yet, the aforementioned difference in UI incidence and severity did not meet the statistical criteria as a p-value <0.0125 was considered significant with the application of Bonferroni correction.

Shape and magnitude of correlations between sEMG values and UI incidence and UI severity as indicated by IIQ-7 scores are shown in Table 3. Correlations between PPC and UI incidence and severity in the episiotomy group were moderately negative by pp12m, and slightly negative at pp24m. In the nonepisiotomy group, correlation between PPC and UI incidence was moderately negative throughout, while the magnitude of correlation between PPC and UI severity declined from moderately negative before pp6m (pp6m included) to slightly negative after pp12m (pp12m included). Similarly, moderately negative correlations were observed between MTC and UI incidence and severity in both groups at baseline (pp6w), yet became unapparent later. The amplitude of preresting baseline also demonstrated a moderately negative correlation with UI incidence and severity in the episiotomy group, and a slightly negative correlation in nonepisiotomy at pp6w. We did not observe any significant correlations between post-baseline resting sEMG values and UI outcomes during the whole time.

4 | DISCUSSION

Few studies to date have dived into the long-term neuromuscular alterations of PFMs after vaginal delivery, let alone vaginal delivery with episiotomy. In this consideration, our study followed through the postpartum electromyography and contraction of PFM in a 2-year time scope, gave comparisons of the episiotomy and nonepisiotomy groups and heuristically delineated the connection between their electrophysiological activities and ability to maintain urinary continence. Our results provide evidence of the value of electromyography as an objective and sensitive indicator of pelvic floor function clinically.

Electromyography is a sensitive method to identify PFM dysfunction and may enable us to better understand the pathophysiology of pelvic floor disorders.[9,14,18] Although sEMG does not directly depict the muscle strength, its amplitudes reflect the number of recruited motor units and thereby the extent of muscle contraction, as electrical activation of muscles initiates their mechanical force production.[8] However, insufficient understanding on how vaginal delivery impacts the PFM electromyography and lack of consensual normative values of vaginal EMG parameters have limited the clinical application of electromyography. Botelho et al.[19] and Gou et al.[6] both documented the loss of muscle contractility seen from electromyography at 6 weeks after childbirth. We provide further reference for the longer-term postpartum electromyography alterations. Regardless of whether or not delivered with episiotomy, sEMG amplitudes increased drastically with time following childbirth. We also introduced the impact of episiotomy into our study scope of postpartum electromyography and found that sEMG of all contractions in the episiotomy group was remarkably lower than that in the nonepisiotomy group in the first year following vaginal delivery, with endurance contraction being the most enduringly affected by episiotomy, whose difference in sEMG amplitude lasted 2 years. All the above findings from our studies and other investigators are consistent with theories that significant stretching and compression during the descent of the fetal head cause injury of PFMs, nerves and connective tissues and prompt denervation of PFM during labor, which takes time to recover. We further showed that episiotomy could add to the childbirth insult to the pelvic floor function and that episiotomy lastingly affects PFM function in addition to vaginal delivery. Presumably, women that met the indication of episiotomy tended to experience more intensive compression from the fetus at the pelvic

TABLE 2 Comparison of the IIQ-7 scores of UI between women delivered with and without episiotomy

	Incidence (*n* [%])				IIQ-7 scores (mean ± SD)			
UI	pp6w	pp6m	pp12m	pp24m	pp6w	pp6m	pp12m	pp24m
Episiotomy (*n* = 200)	39 (19.5)	26 (13.0)	10 (5.0)	9 (4.5)	21.61 ± 16.08	18.62 ± 13.75	14.29 ± 7.10	15.47 ± 11.87
Nonepisiotomy (*n* = 162)	18 (11.1)	9 (6.2)	6 (4.3)	5 (3.1)	14.02 ± 12.60	11.11 ± 5.83	7.93 ± 2.46	9.52 ± 3.37
$\chi 2/t$	4.75	6.57	0.36	0.48	1.77	2.26	2.59	1.41
p	0.03	0.04	0.55	0.49	0.08	0.03	0.02	0.19

Note: UI, urinary incontinence; IIQ-7, Urinary Incontinence Impact Questionnaire Short Form; The IIQ-7 scale ranges from 0–100; Incidence of UI, the occurrence ratio of IIQ-7 scores above zero; a square-test was performed in the analysis of the comparison of the incidence of UI symptoms between two groups; Mann–Whitney U analysis was performed in the analysis of the comparison of the IIQ-7 scores; *p*-value <0.0125 was considered statistically significant.

TABLE 3 Correlation analysis of sEMG values and outcomes of IIQ-7 scores

			PFC				MEC		PREBR
sEMG (μv)			pp6w	pp6m	pp12m	pp24m	pp6w	pp6m	pp6w
Episiotomy (*n* = 200)	IIQ-7 scores	*r*	−0.58	−0.43	−0.41	−0.38	−0.38	−0.30	−0.44
		p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	UI incidence	*r*	−0.56	−0.40	−0.41	−0.37	−0.49	−0.18	−0.40
		p	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.001
Nonepisiotomy (*n* = 162)	IIQ-7 scores	*r*	−0.49	−0.42	−0.36	−0.33	−0.45	−0.30	−0.36
		p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	UI incidence	*r*	−0.54	−0.40	−0.40	−0.40	−0.44	−0.30	−0.33
		p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Note: Spearman's correlation analysis was used to analyze the correlation between EMG data and QoL outcomes of UI; *r*, the correlation coefficient; *p*-value <0.0125 was considered statistically significant.

Abbreviations: EMG amplitude: MEC, average mean amplitude of endurance contraction; PFC, average peak amplitude of maximal fast contraction; PREBR, average mean amplitude of rest prebaseline; sEMG, surface electromyography; μV, microvolts.

floor, and pelvic tissue damage was aggravated by the sharp instrumental injury from episiotomy.[4] However, absence of prelabor and nonpregnancy data of the study cohort prevent us from drawing a definitive conclusion on whether vaginal delivery or episiotomy weakened muscle fibers.

Compromised PFM function in women who deliver with episiotomy has been corroborated by different methodologies. Sartore et al.[20] and Myers et al.[21] documented that episiotomy is associated with lower PFM strength measured by manometry from the third to the sixth postpartum month. We also present evidence on the negative effect of episiotomy in a two-year postpartum duration. However, the effect of episiotomy on PFM function is controversial. Contrary to our results, Bø et al.[22] did not find any statistically significant differences in PFM strength and endurance in women with or without episiotomy. Different methodologies may explain the contradictory findings: vaginal manometry applied by Bø et al. measured squeeze pressure in the vagina to acquire the strength and endurance while EMG recorded the electrical activities. Although neither method directly measures the muscle strength, we believe sEMG to be more sensitive and accurate as electrophysiological activation and muscle contractions are highly coupled.[7] Given that there is no gold standard to evaluate PFM function, using different methods is recommended for deeper understanding of PFM function, and vaginal electromyography could be an ideal routine postpartum assessment. Although the differences in PFM sEMG were statistically significant between women after first vaginal birth with and without episiotomy, whether such difference is still clinically relevant requires further investigation.

Vaginal delivery is associated with increased risk for all types of UI for at least 1 year postpartum.[2,23] Few studies have bridged the manifestations of UI with the underlying pathophysiology of PFM damage with experimental evidence. Using sEMG as a mirror of PFM physiological activity, we discovered a correlation between UI symptoms and sEMG amplitudes. The disease-specific quality of life questionnaire is the most common method to determine the incidence and severity of UI,[5,24] and hereby we adopted the IIQ-7 questionnaire, whose high scores indicated greater severity. We discovered that low sEMG amplitudes had a slight to moderate correlation with high scores of IIQ-7 regardless of episiotomy history. Given that UI was asymptomatic among most primiparous women (327, 83.4%), the correlation reliability in our study was not as high as that reported from urinary incontinent patients ($r = 0.86$).[14] Also noteworthy is that such negative correlation between sEMG amplitudes and UI outcomes persisted for 2 years in terms of fast contraction and

6 months in terms of endurance contraction. Previous studies[10] and those of other investigators[6,18,25] have also identified that patients with UI showed lower EMG amplitudes of fast contraction, providing clinical evidence for the different roles that fast and slow twitch fibers play on the PFM function. These two types of fibers contribute to different pelvic floor functions: fast fibers for controlling urination and defecation, and slow fibers for supporting pelvic organs.[26] The constant association between EMG amplitudes of fast contraction and UI incidence and severity shown in this study can be explained as follows: the lower the maximal fast contraction amplitude may be responsible for poor urination and defection control, thus inducing the more severe incontinence complaints reported by the patient. Our findings showed that increasing sEMG amplitudes of PFM contraction by physical exercise of fast and slow twitch fibers could possibly serve as a solution to UI. In fact, the clinical approach of UI treatments[2,15,27] are consistent with our study. The correlation between PFM contractile electrophysiology and UI symptoms might be further confirmed during pregnancy for the according musculoskeletal changes and high incidence of UI.[28] However, it is difficult to obtain PFM sEMG data of pregnant women without ethical permission.

Several functional assessments of PFM are used in both clinical and research settings.[5] As no methods of measuring the PFM function are perfect, it is difficult to state that one method is superior to the next. Manometry and intravaginal sEMG are both reliable instruments for measuring PFM contraction (strength or activation). Manometry which measures the vaginal squeeze pressure can be considered to represent strength and actual capacity of the woman.[1] However, its results are not directive measurement of PFM activity and cannot reflect PFM resting tone.[29] Electromyography is the only method to measure PFM activity directly, capture PFM endurance and voluntary activity, and possible neuromuscular injury to pelvic floor caused by vaginal delivery.[29] Although mediolateral episiotomy has been documented to result in a decrease in injury to the levator ani muscle and occurrence of pelvic floor disorders,[4] the small but significant difference of sEMG between both groups indicated the possible influence of episiotomy on imbalance in the muscular tissue or even reinnervation. Our results confirm that sEMG recordings are a useful tool in understanding both neural control of the pelvic floor and its pathology in cases of neurological or traumatic lesions that may result in UI.[30]

This study had several limitations. First, we excluded 7.7% (52/676) of participants with a high risk of serious levator ani muscle tear. Such a tear might possibly reduce the ability of participants to contract the PFM and generate sEMG amplitudes; meanwhile, it was unethical to involve participants in a long-term observational study without clinical intervention. Accordingly, our findings are not generalizable to women with serious levator ani muscle injury at first childbirth,[3] who are quite likely to be referred for further treatment because of clinical complaints of pelvic floor dysfunction. Second, we only used the IIQ-7 questionnaire to indicate UI symptoms, while other questionnaires such as UDI-6 were also applicable. Third, the interference of crosstalk from deep hip and abdominal muscles in sEMG outcomes is unavoidable.[9] However, even with the high risk of crosstalk from nearby muscle groups in vaginal EMG evaluation, Grape et al.[8] reported that sEMG demonstrated significant test–retest reliability and effectiveness. In this study, we adopted the following means to reduce interference: applying a standard sEMG assessment method,[14] using a bipolar vaginal electrode[8] and excluding the participants who performed incorrect PFM contractions. Last, but not least, the correlation between vaginal sEMG and PFM dysfunction awaits further validation in studies that investigate other pelvic floor disorders and different modes of delivery. We would also like to bring pelvic floor health in younger women even before pregnancy to the attention of the public and look forward to building a larger EMG value database that involves pre-pregnant and prelabor EMG in addition to postpartum data.

5 | CONCLUSION

Women delivered with episiotomy demonstrated lower PFM electrical activity, as reflected by lower sEMG amplitudes of PFM contraction in 2 years following childbirth. In addition, sEMG values of PFM fast contraction had a moderately negative correlation with the incidence and severity of UI.

AUTHOR CONTRIBUTIONS

LM designed the research; LM, DXD and LQB contributed to planning and interpretation; LM, LPP, YCX, LYH, LYX, GTZ and FQ performed the research; ZGF analyzed the data; and LM and YCX wrote the article. All authors commented and approved the final version.

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CONFLICT OF INTEREST

All authors declare they have no competing interests.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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