

Original Article



Does Prenatal SARS-CoV-2 Infection Exacerbate Postpartum Lower Urinary Tract Symptoms? A Multicenter Retrospective Cohort Study

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Abstract

Objective Coronavirus disease 2019 (COVID-19) can result in fatigue and post-exertional malaise; however, whether severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection exacerbates lower urinary tract symptoms (LUTS) is unclear. This study investigated the association between prenatal SARS-CoV-2 infection and postpartum LUTS.

Methods A multicenter, retrospective cohort study was conducted at two tertiary hospitals in China from November 1, 2022, to November 1, 2023. Participants were classified into infected and uninfected groups based on SARS-CoV-2 antigen results. LUTS prevalence and severity were assessed using self-reported symptoms and the Incontinence Impact Questionnaire-Short Form (IIQ-7). Pelvic floor muscle activity was measured using electromyography following the Glazer protocol. Group comparisons were performed to evaluate the association of SARS-CoV-2 infection with LUTS and electromyography parameters, with stratified analyses conducted using SPSS version 26.0.

Results Among 3,652 participants (681 infected, 2,971 uninfected), no significant differences in LUTS prevalence or IIQ-7 scores were observed. However, SARS-CoV-2 infection was an independent factor influencing the electromyographic activity of the pelvic floor muscles (mean tonic contraction amplitudes), regardless of delivery mode ($P = 0.001$).

Conclusion Prenatal SARS-CoV-2 infection was not significantly associated with an increased risk of postpartum LUTS but independently altered pelvic floor muscle electromyographic activity, suggesting potential neuromuscular effects.

Key words: COVID-19 post-acute sequelae; Lower urinary tract symptoms; SARS-CoV-2; Electromyography

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic from 2020 to 2023 posed unprecedented challenges to global health, with more than 771 million confirmed cases worldwide, resulting in medical and economic burdens^[1]. COVID-19 has widespread and complex effects on the body, with approximately 10% of individuals infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) developing post-acute sequelae, manifesting as a variety of symptoms across multiple organ systems, including cardiovascular disease, cerebrovascular disease, chronic fatigue syndrome, and dysautonomia^[2]. The long-term consequences and mechanisms of these sequelae remain incompletely understood, highlighting the need for a deeper understanding to improve health management and monitoring strategies related to the long-term effects of COVID-19.

Several studies have reported that acute SARS-CoV-2 infection may cause lower urinary tract symptoms (LUTS)^[3-5]. LUTS consist of storage, voiding, and post-micturition symptoms, primarily including urinary frequency, urgency, and urinary incontinence (UI), as defined by the International Continence Society^[6]. Large population-based epidemiological studies have indicated that the prevalence of LUTS among women ranges from 55.5% to 66.6%^[7-9], with nocturia, urgency, and UI being the most common symptoms. It is well established that pregnancy and childbirth are independent risk factors for LUTS. The prevalence of UI in women increases over time after delivery, exceeding 30% after 15 years^[10,11], significantly impairing both quality of life and mental well-being^[12,13]. However, whether SARS-CoV-2 infection exacerbates LUTS remains controversial. While some studies have reported a higher prevalence of LUTS associated with SARS-CoV-2 infection^[3,5,14-16], others have observed a lower prevalence and severity of UI among women during the COVID-19 pandemic^[17]. The inconsistency and limitations of study populations leave gaps in our understanding of the impact of prenatal SARS-CoV-2 infection on postpartum LUTS and the potential underlying mechanisms. LUTS may result from various anatomical and functional changes in the pelvic floor muscle (PFM). Case reports have indicated that women experienced UI after recovering from COVID-19, with UI related to PFM weakness benefiting from physical therapy^[18]. Additionally,

previous studies have demonstrated that COVID-19 can affect the musculoskeletal system, resulting in post-exertional malaise^[2]. Since PFM-related disorders are often associated with electrophysiological abnormalities observed through PFM electromyography (EMG)^[19,20], and given that our previous study showed consistency between UI outcomes based on questionnaire and EMG values^[21], it might be meaningful to explore postpartum LUTS and PFM activity using subjective self-report symptoms and questionnaires, as well as objective EMG assessment.

This study aimed to reveal the correlation between prenatal SARS-CoV-2 infection and postpartum LUTS, as assessed through self-reported symptoms and PFM EMG. We hope to gain valuable evidence and new insights into the underlying mechanisms leading to postpartum LUTS after prenatal SARS-CoV-2 infection, as well as the clinical implications and future research directions.

METHODS

Participants

This hospital-based, multicenter, retrospective cohort study was conducted at two tertiary hospitals across northern and southwest China, sequentially involving all women attending postnatal consultations from November 1, 2022, to November 1, 2023. Electronic medical records were used for eligibility screening, group allocation, and baseline analysis. SARS-CoV-2 detection results and demographic characteristics were obtained from medical records. Given the variability in the onset and duration of COVID-19 post-acute sequelae across individuals and symptom types^[22], along with findings from previous studies on postpartum UI^[21], eligible postnatal consultations were set between 6 and 12 weeks after childbirth. The inclusion criteria were: (1) confirmed prenatal SARS-CoV-2 detection results and (2) age > 18 years. The exclusion criteria were as follows: (1) no SARS-CoV-2 detection results during pregnancy, (2) history of UI or neuromuscular diseases before pregnancy, (3) history of pelvic floor surgery, (4) instrumented delivery, (5) third/fourth-degree perineal tears or episiotomy, (6) active urinary tract infection, (7) taking anti-coronavirus drugs, (8) severe COVID-19, and (9) participation in rehabilitation intervention. Ultimately, based on SARS-CoV-2 antigen positivity or negativity, there were 681 and 2,971 women in the SARS-CoV-2 infected and uninfected groups, respectively. The

study was performed in accordance with the Declaration of Helsinki and approved by the Beijing Hospital Medical Ethics Committee (2019BJYYEC-014-02) on February 15, 2019.

During postnatal consultations, eligible women self-reported postpartum LUTS, completed questionnaires, and underwent PFM EMG assessments. LUTS were categorized into storage (stress and urge UI, frequency) and voiding (terminal dribbling) symptoms. The definitions followed those of the International Continence Society^[6]. Stress UI was defined as involuntary leakage during exertion, such as sneezing or coughing, whereas urge UI was defined as involuntary leakage immediately preceded by urgency. Participants were considered to have voiding frequency if they reported voiding too often per day. Terminal dribbling was defined as a prolonged final part of micturition. To account for COVID-19 post-acute sequelae, symptoms were defined as those occurring ≥ 3 months after infection and persisting for at least two months based on the World Health Organization guidelines^[23]. Potential confounders, including age, body mass index (BMI), postpartum time, mode of delivery, and SARS-CoV-2 infection period, were defined and compared between groups. BMI (kg/m^2) was calculated using weight and height, with categories of underweight (< 18.5), normal weight ($18.5\text{--}24.0$), overweight ($24.0\text{--}28.0$), and obesity (≥ 28). Postpartum time was defined as the duration from childbirth to the first postnatal consultation. The period

of SARS-CoV-2 infection was categorized into first (T1: < 14 weeks of gestation), second (T2: 14–28 weeks), and third (T3: ≥ 28 weeks) trimester. A physiotherapist examined the participants, collected self-reported LUTS, assisted with completing questionnaires, and conducted EMG measurements (Figure 1). The primary outcomes were the prevalence of self-reported LUTS and the questionnaire scores. The secondary outcome was the EMG value.

Questionnaires

We collected the Incontinence Impact Questionnaire-Short Form (IIQ-7)^[24], a patient-reported outcome measure designed to assess the frequency, severity, and impact on quality of life. IIQ-7 (range: 0–100) reflects higher scores, denoting more severe symptoms and lower quality of life. IIQ-7 has been translated into Chinese and validated in China^[25].

EMG

EMG signals were detected using “MLD V2 Vaginal Electrode” intravaginal electrodes (Medlander Medical Technology Inc.) and processed using Biostim software (Medlander Medical Technology Inc.). The Glazer protocol was used to standardize the PFM activity^[20,26]. It consisted of a standardized sequence of muscle contractions and relaxations in the supine position. Before the protocol, the participants were instructed on how to

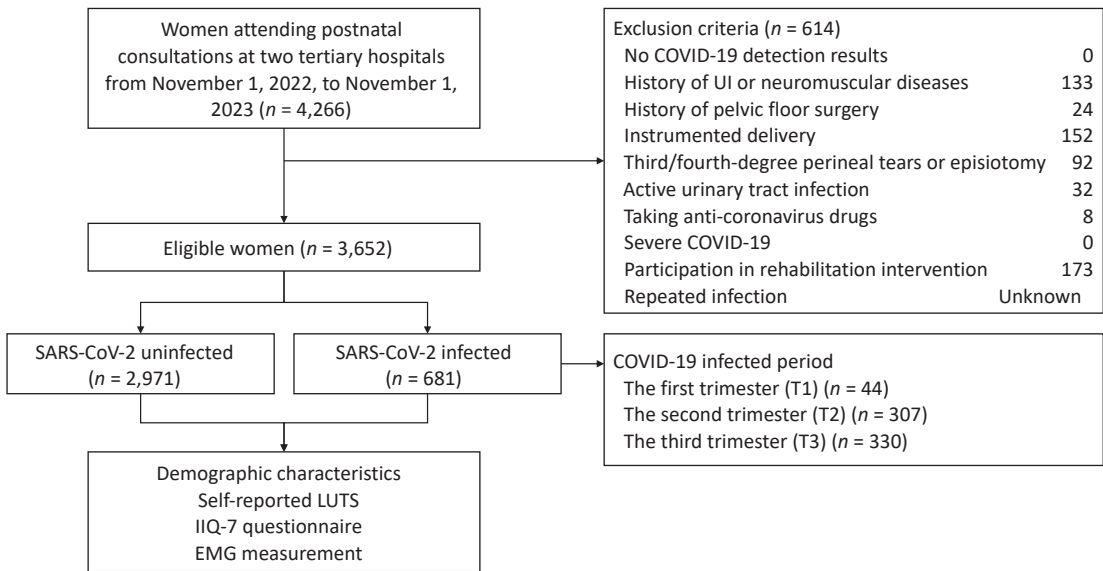


Figure 1. Flowchart of the Study Enrollment. SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; LUTS, lower urinary tract symptoms; IIQ-7, Impact Questionnaire Short Form questionnaire; EMG, electromyography; COVID-19, coronavirus disease 2019; UI, urinary incontinence; T1, first trimester; T2, second trimester; T3, third trimester.

isolate the abdominal, gluteal, or adductor muscles to prevent interference with EMG values. They were trained to differentiate between contractions by practicing maximal fast and endurance contractions. After a 10-minute rest in the supine position, the EMG test was initiated using voice prompts. The protocol included four steps: 60-second pre-baseline rest (PREBR), five maximal phasic contractions with 10-second rests in between (PPC), five 10-second tonic contractions alternated with 10-second rests (MTC), and 60-second post-baseline rest (POSTBR). The mean amplitude (μV) was used for each of the four EMG values. Minimal activation of the abdominal, gluteal, or adductor muscles was monitored during the contractions.

Statistical Analysis

The prevalence of self-reported LUTS, severity of UI (indicated by questionnaires), and EMG values (PREBR, PPC, MTC, and POSTBR) were compared between the SARS-CoV-2 infected and uninfected groups. We performed the Kolmogorov-Smirnov test for continuous variables to confirm normality. Categorical variables are described as numbers and percentages. Continuous variables following a normal distribution are reported as mean \pm standard deviation. Categorical variables were analyzed using the chi-square test, while continuous normal variables were analyzed using *t*-tests. ANOVA was used for comparisons across multiple groups. Confounder-adjusted estimations were conducted using stratified analyses, logistic regression was used for dichotomous variables, such as the prevalence of self-reported LUTS, and general linear models were used for continuous variables, such as questionnaire scores and EMG values. General linear models were applied, with SARS-CoV-2 infection (infected vs. uninfected) and mode of delivery (cesarean section vs. vaginal delivery) as factors, and postpartum time as a covariate. Bonferroni correction was applied to adjust the α level to control for the risk of a type I error in multivariate comparisons. A *P*-value of < 0.05 was considered statistically significant in bivariate comparisons, while a $P < 0.01$ was considered statistically significant in multivariate comparisons. All statistical analyses were conducted using SPSS software (version 26.0; SPSS Inc., Chicago, IL, USA).

RESULTS

Participant Demographic Characteristics

All continuous variables followed a normal

distribution. The mean age of the participants was 33 years, with a mean BMI of 23.31 kg/m^2 and a mean postpartum period of 64 days. There were 681 women in the SARS-CoV-2 infected group and 2,971 in the SARS-CoV-2 uninfected group. In the SARS-CoV-2 infected group, 44 (6.46%) women were infected during T1, 307 (45.08%) during T2, and 330 (48.46%) during T3. The two groups were similar in terms of age, BMI, and postpartum time. However, a higher cesarean section rate was observed in the SARS-CoV-2 infected group (26.1% vs. 22.4%, $P = 0.038$) (Table 1).

Prevalence of Self-reported LUTS and Questionnaire Scores in SARS-CoV-2 Infected and Uninfected Groups

No significant differences were observed in the prevalence of self-reported LUTS between the SARS-CoV-2 infected and uninfected groups (Table 2). Similarly, there were no significant differences in IIQ-7 scores between the two groups (Table 3). Stratified analysis showed no significant differences in IIQ-7 scores between the SARS-CoV-2 infected and uninfected groups, regardless of vaginal delivery or cesarean section. In both groups, women who delivered vaginally had higher IIQ-7 scores. Based on demographic characteristics and our previous studies, logistic regression was performed to assess the risk of developing LUTS, revealing no significant differences in stress UI ($OR = 0.970$, $P = 0.776$), urge UI ($OR = 0.965$, $P = 0.762$), frequency ($OR = 0.855$, $P = 0.159$), or terminal dribble ($OR = 1.031$, $P = 0.776$) after SARS-CoV-2 infection. The general linear model found no interaction between SARS-CoV-2 infection and mode of delivery on IIQ-7 ($P = 0.440$) scores, and no main effect of SARS-CoV-2 infection on IIQ-7 ($P = 0.068$). However, the main effect of mode of delivery indicated that IIQ-7 scores ($P < 0.001$) were lower in women who underwent cesarean section (Table 3).

EMG Values in SARS-CoV-2 Infected and Uninfected Groups

EMG values for PPC ($P = 0.045$), MTC ($P < 0.001$), and POSTBR ($P = 0.045$) were significantly higher in the SARS-CoV-2 infected group than in the uninfected group. Stratified analyses showed that MTC was significantly higher in the SARS-CoV-2 infected group among women who underwent either vaginal delivery ($P = 0.008$) or cesarean section ($P = 0.013$) (Figure 2). The general linear model identified SARS-CoV-2 infection as an independent factor influencing MTC ($P = 0.001$), with

no significant main effects on other EMG values (Table 4). Additionally, an interaction between SARS-CoV-2 infection and the mode of delivery was

observed for PPC ($P = 0.046$). Women who underwent cesarean section showed higher EMG values than those who underwent vaginal delivery

Table 1. The demographic characteristics of participants in the SARS-CoV-2 infected and uninfected groups

Characteristics	SARS-CoV-2 infected group ($n = 681$)	SARS-CoV-2 uninfected group ($n = 2,971$)	<i>P</i> -value
Age, years	32.78 \pm 3.91	32.69 \pm 4.12	0.684
18–	203 (29.8)	880 (29.6)	0.732
30–	457 (67.1)	2015 (67.8)	
≥ 40	21 (3.1)	76 (2.6)	
BMI, kg/m ²	23.43 \pm 3.27	23.28 \pm 3.08	0.321
< 18.5 (underweight)	23 (3.4)	103 (3.5)	0.283
18.5– (normal weight)	391 (57.4)	1,803 (60.7)	
24.0– (overweight)	215 (31.6)	827 (27.8)	
≥ 28.0 (obesity)	52 (7.6)	238 (8.0)	
Postpartum time, day	66 \pm 48	63 \pm 53	0.262
Mode of delivery			0.038
Vaginal delivery	503 (73.9)	2,305 (77.6)	
Cesarean section	178 (26.1)	666 (22.4)	

Note. Data are presented as mean with standard deviation or number with percentage (%); $P < 0.05$ denotes statistical significance. SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; BMI, body mass index.

Table 2. Comparison of the prevalence of self-reported LUTS between the SARS-CoV-2 infected and uninfected groups

LUTS	SARS-CoV-2 infected group ($n = 681$)	SARS-CoV-2 uninfected group ($n = 2,971$)	<i>P</i> -value COVID-19 infection
Storage symptoms			
Stress UI	32 (4.7)	166 (5.6)	0.356
Vaginal delivery	26 (5.2)	140 (6.1)	0.422
Cesarean section	6 (3.4)	26 (3.9)	0.769
Urge UI	148 (21.7)	663 (22.3)	0.741
Vaginal delivery	107 (21.2)	501 (21.8)	0.779
Cesarean section	41 (23.2)	162 (24.1)	0.801
Frequency	78 (11.4)	374 (12.6)	0.641
Vaginal delivery	61 (12.1)	303 (13.2)	0.513
Cesarean section	17 (9.6)	71 (10.5)	0.713
Voiding symptoms			
Terminal dribble	65 (9.5)	259 (8.7)	0.494
Vaginal delivery	51 (10.1)	225 (9.8)	0.812
Cesarean section	14 (7.9)	34 (5.1)	0.143

Note. Data are presented as number with percentage (%); $P < 0.05$ denotes statistical significance. LUTS, lower urinary tract symptoms; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; UI, urinary incontinence; COVID-19, coronavirus disease 2019.

(Figure 2). The main effects of mode of delivery indicated that PREBR ($P < 0.001$), PPC ($P < 0.001$), MTC ($P < 0.001$), and POSTBR ($P < 0.001$) were all higher in women who underwent cesarean section (Table 4).

The Impact of SARS-CoV-2 Infected Period on the Prevalence of Self-reported LUTS, Questionnaire Scores, and EMG Values

No significant differences were observed in the prevalence of self-reported LUTS, questionnaire scores, or EMG values between T1, T2, and T3. A significant difference was found in MTC when comparing the groups at different SARS-CoV-2 infection periods with the uninfected group ($P = 0.001$). Pairwise comparisons revealed that only women infected with SARS-CoV-2 during the second trimester had significantly higher MTC ($P = 0.001$) than those without infection (Figure 3). The general linear model showed no interaction between the SARS-CoV-2 infection period and other factors. However, after post-hoc analysis, the SARS-CoV-2 infection period had a main effect, with MTC being significantly higher in women infected during the second trimester ($P = 0.007$).

DISCUSSION

In this study, we investigated the correlation between prenatal SARS-CoV-2 infection and postpartum LUTS, as assessed using self-reported symptoms and PFM EMG. Our findings showed that prenatal SARS-CoV-2 infection did not exacerbate postpartum LUTS; however, a higher average mean amplitude of tonic contractions in EMG assessment was observed among infected women, particularly those infected during the second trimester. These results provide valuable evidence and new insights into the underlying mechanisms leading to postpartum LUTS after prenatal SARS-CoV-2 infection.

Vaginal delivery is a well-known risk factor for LUTS because of increased PFM loading and injuries^[27]. Our analysis revealed a significantly higher cesarean section rate in the SARS-CoV-2 infected group, which is consistent with previous studies^[28]. Additionally, in both the SARS-CoV-2 infected and uninfected groups, women who underwent vaginal delivery exhibited higher IIQ-7 scores. Vaginal delivery, compared with cesarean section, is associated with an almost twofold increase in the risk of long-term stress UI, with the greatest risk observed in younger women^[27].

We employed various methods to perform confounder-adjusted estimations of the LUTS outcomes. The conclusion was controversial, as several studies have reported a higher prevalence of LUTS associated with SARS-CoV-2 infection^[5], particularly urinary frequency and nocturia^[3,15,16]. Another study indicated that the severity of COVID-19 significantly affects LUTS^[14]. However, these studies focused on hospitalized patients in the acute infection phase, providing limited insight into the potential molecular mechanisms^[15]. This negative effect of SARS-CoV-2 infection on LUTS may subside after the acute phase. In contrast, Ferrari et al. found a lower prevalence and severity of UI among women during the COVID-19 pandemic, focusing on the impact of the pandemic rather than the SARS-CoV-2 infection itself^[17].

We also assessed PFM activity to specifically investigate the impact of prenatal SARS-CoV-2 infection on the associated potential mechanisms of postpartum LUTS. Given the subjectivity of questionnaires, we used EMG as a sensitive method to detect PFM activity. Our previous study confirmed the consistency between EMG values and IIQ-7 scores, which increased drastically with time following childbirth^[21]. Several studies have proven that EMG is a reliable tool for assessing PFM activity by directly measuring the muscle motor unit action and reflecting the integrated activity of physiological

Table 3. Comparison of questionnaire scores between the SARS-CoV-2 infected and uninfected groups

Questionnaire scores	SARS-CoV-2 infected group (n = 681)	SARS-CoV-2 uninfected group (n = 2,971)	P-value COVID-19 infection
IIQ-7	6.23 ± 16.73	7.40 ± 16.91	0.391
Vaginal delivery	6.47 ± 16.32	7.98 ± 18.82	0.293
Cesarean section	3.08 ± 9.42	3.55 ± 14.13	0.795

Note. Data are presented as mean with standard deviation; $P < 0.05$ denotes statistical significance. SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; IIQ-7, Impact Questionnaire Short Form questionnaire; COVID-19, coronavirus disease 2019.

processes^[20]. Yang et al. identified pre-baseline rest and endurance contraction as the most correlated values for postpartum stress UI^[29], while Ptazkowski et al. found phasic and endurance contractions to be the most significant in postmenopausal stress UI^[30]. Interestingly, we observed a higher average mean amplitude of tonic contractions in the EMG assessment of postpartum women with prenatal SARS-CoV-2 infection. Type I muscle fibers, recruited by tonic contractions, are associated with supporting the pelvic organs, whereas type II muscle fibers engaged during phasic contractions improve continence by preventing leakage during abdominal pressure-increased activities^[31]. Our results

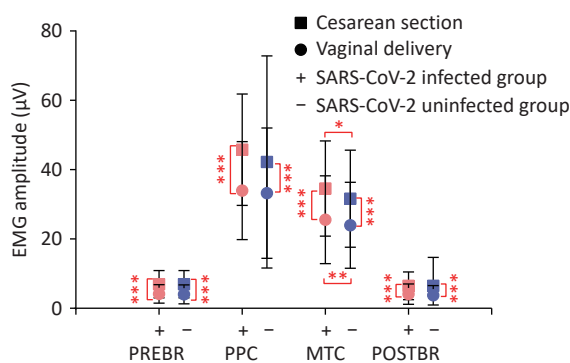


Figure 2. Stratified analyses of EMG values in the SARS-CoV-2 infected and uninfected groups. $P < 0.05$ denotes statistical significance. EMG, electromyography; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; PREBR, average mean amplitude of pre-baseline rest; PPC, average mean amplitude of maximal phasic contractions; MTC, average mean amplitude of tonic contractions; POSTBR, average mean amplitude of post-baseline rest.

suggested that, after SARS-CoV-2 infection, the activity of type I muscle fibers of PFM was improved. This finding allows for better tonic contractions during PFM training. Perinatal women with COVID-19 post-acute sequelae exhibit symptoms similar to those of the general population, such as fatigue^[32], and the underlying pathophysiological mechanism of musculoskeletal symptoms remains poorly understood^[33,34]. One pathophysiological mechanism indicated that reduced skeletal muscle strength after SARS-CoV-2 infection is characterized by local and systemic metabolic disturbances^[35,36]. A pilot study showed that fatigue in COVID-19 post-acute sequelae coincided with oxidative stress^[37]. Similarly, another study found that exercise intolerance associated with COVID-19 post-acute sequelae is defined by impaired aerobic and anaerobic energy production. Peak venous succinate levels may serve as a potential biomarker of COVID-19 post-acute sequelae^[38]. Functional and morphological differences in muscle mitochondria have been discovered in COVID-19 post-acute sequelae, which are probably direct virus-induced alterations^[39]. A recent review reported that the mitochondrial dysfunction and ionic disturbance caused by sodium-induced calcium overload are the most likely causes of exertional intolerance and post-exertional malaise^[40]. Another pathophysiological mechanism is related to the muscle fiber phenotype shift. Sousa et al. suggested that physiotherapy could yield positive outcomes for women with stress UI caused by muscle weakness following SARS-CoV-2 infection^[18]. Since muscle strength is typically significantly affected by fatigue^[41], which depends on the recruitment of motor units, a shift toward less oxidative and more glycolytic fiber phenotypes, as demonstrated by Appelman et al., might reduce exercise capacity after SARS-CoV-2 infection^[42].

Table 4. Interaction analyses of SARS-CoV-2 infection and other factors on EMG values

EMG values	SARS-CoV-2 infected group (n = 681)		SARS-CoV-2 uninfected group (n = 2,971)		P-value SARS-Cov-2 infection	P-value Interaction	P-value Mode of delivery
	Vaginal delivery (n = 504)	Cesarean section (n = 177)	Vaginal delivery (n = 2,298)	Cesarean section (n = 673)			
PREBR	3.99 ± 2.48	6.98 ± 3.95	3.89 ± 2.59	6.97 ± 3.94	0.712	0.785	< 0.001
PPC	32.19 ± 13.41	45.91 ± 15.99	32.58 ± 16.81	42.23 ± 30.75	0.095	0.046	< 0.001
MTC	24.60 ± 12.56	34.71 ± 13.68	23.68 ± 12.23	31.55 ± 13.99	0.001	0.082	< 0.001
POSTBR	3.98 ± 2.80	6.49 ± 4.04	3.63 ± 2.74	6.51 ± 8.20	0.507	0.411	< 0.001

Note. $P < 0.05$ denotes statistical significance. EMG, electromyography; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; PREBR, average mean amplitude of pre-baseline rest; PPC, average mean amplitude of maximal phasic contractions; MTC, average mean amplitude of tonic contractions; POSTBR, average mean amplitude of post-baseline rest.

However, given that EMG assessments involved brief contractions that might not induce significant fatigue, and considering the fatigue resistance of type I muscle fibers, the unimpaired PFM activity in our study could be partially explained.

Another perspective is that improved pelvic organ support after SARS-CoV-2 infection might be associated with reduced activity levels. One study reported a lower prevalence and severity of UI among women during the COVID-19 pandemic, ascribing this “protective” effect to decreased physical exertion^[17]. Physical activity levels decreased following the COVID-19 outbreak, particularly among perinatal women. Shaw et al.^[43] found that moderate to vigorous activity was associated with worse PFM support in postpartum women compared with sedentarism. A trial comparing people with and without COVID-19 post-acute sequelae showed that patients had lower aerobic capacity and less muscle strength, so it recommended cautious exercise adoption to prevent further muscle deconditioning^[44].

The reduction in outdoor activities and prolonged bed rest likely alleviated the compression effects on PFM, potentially lessening their impact on PFM activity. Considering that the difference in EMG values between the two groups was minimal (a few microvolts) and was not reflected in LUTS outcomes, this statistical difference in these findings might lack clinical relevance.

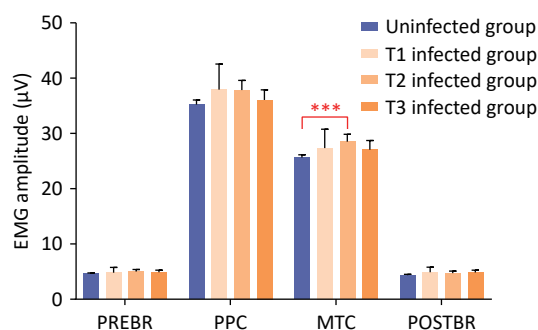


Figure 3. Pairwise comparisons of EMG values among women in T1, T2, T3, and uninfected groups. $P < 0.01$ denotes statistical significance. EMG, electromyography; T1, first trimester; T2, second trimester; T3, third trimester; PREBR, average mean amplitude of pre-baseline rest; PPC, average mean amplitude of maximal phasic contractions; MTC, average mean amplitude of tonic contractions; POSTBR, average mean amplitude of post-baseline rest.

The strength of our multicenter study lies in its large sample size, which enabled a comprehensive understanding of COVID-19 post-acute sequelae in perinatal women by analyzing postpartum LUTS. This study utilized both subjective symptom-related questionnaires and objective EMG assessment, with the latter involving disposable vaginal electrodes to prevent cross-infection while providing direct electrophysiological data on PFM. However, this study had several limitations. First, selection bias could not be avoided. This hospital-based study included only postpartum women attending postnatal consultation, limiting its generalizability, but can serve as supplementary evidence for other population-based studies. Second, this study mainly investigated the severity of UI among LUTS, as its high prevalence in postpartum women potentially reflects trends in other LUTS. However, the remaining LUTS have also been reported in individuals with COVID-19 post-acute sequelae^[5]. Third, the short follow-up period of 6–12 weeks postpartum may not have captured long-term effects. Previous studies found that two-thirds of individuals with COVID-19 post-acute sequelae had persisting disease for more than a year^[45]. Continued follow-up is necessary to understand the lasting impact of COVID-19 post-acute sequelae on postpartum LUTS.

CONCLUSION

Prenatal SARS-CoV-2 infection was not significantly associated with an increased risk of postpartum LUTS. However, it independently altered PFM electromyographic activity, suggesting potential neuromuscular effects of the virus. The discrepancy between PFM electrophysiology and clinical symptoms highlights the need for long-term follow-up to better understand COVID-19 post-acute sequelae.

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Competing Interests The authors declare no conflict of interest.

Ethics The study was performed in accordance with the Declaration of Helsinki and approved by the Beijing Hospital Medical Ethics Committee (2019BJYYEC-014-02) on February 15, 2019.

Authors' Contributions Data analysis, Writing:

Yuhan Lyu, Min Li (Beijing Hospital). Study design, Self-reported symptoms collection: Min Li (Beijing Hospital). Data collection: Yuhan Lyu, Pingping Li, Yue Yu, Yaxin Liang, Lin Liang Min Li (The First People's Hospital of Yunnan Province), and Xiaomei Wu. EMG measurement: Tianzi Gai, Su Pan. Data analysis: Yuhan Lyu, Huiqing Yao.

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