

Differential Maternal Physiological Stress Responses During Rooming-In: High Stress in Newborn Sleeping versus Relief in Breastfeeding

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Background: Postpartum stress (PPS) significantly risks maternal-infant health, yet how specific newborn behavioral states are dynamically associated with maternal physiological stress during rooming-in remains unknown.

Purpose: This study examined the associations among maternal stress, rooming-in levels, and newborn states during early postpartum hospitalization.

Methods: A prospective repeated-measures observational study with consecutive sampling was conducted at a hospital in Taiwan. Eligible participants were healthy, full-term, primiparous women after vaginal birth accompanied by a partner; those with clinical complications or cardiac arrhythmias were excluded. A total of 43 women completed the overall longitudinal assessments. Maternal normalized low frequency (nLF) was monitored via portable ECG across four newborn states (crying, breastfeeding, being held, sleeping). Among them, a subgroup of 30 mothers provided complete newborn state diaries and continuous ECG data for synchronized analysis. Data were analyzed with descriptive statistics, paired samples *t*-tests, and correlation tests.

Results: Overall maternal nLF increased significantly from Day 1 (T1) to Day 3 (T2) ($p=0.022$, $N=43$). No significant associations were observed between nLF and rooming-in levels ($p>0.05$, $n=30$). Contrary to our hypothesis, 73% of participants experienced the highest level of maternal physiological stress while the infant slept ($nLF=65.4\%$), suggesting a state of situational alertness. Conversely, breastfeeding demonstrated a distinct stress-relieving potential, with 40% of participants exhibiting their lowest stress levels ($nLF=60.2\%$).

Conclusion: Infant sleep is linked to maternal situational alertness rather than rest, while breastfeeding offers stress-relief potential. This study provides preliminary exploratory evidence that maternal autonomic activity varies across caregiving contexts.

Plain Language Summary: Rooming-in where mothers and newborns stay together after birth, is widely encouraged because it supports breastfeeding and bonding. However, staying close to the newborn all the time may also affect a mother's physical stress levels and recovery during the early days after delivery. In this study, we used heart rate variability (HRV), a body signal linked to stress and nervous system activity, to understand how mothers physically respond to different newborn states during rooming-in care.

We found that mothers showed higher physical stress levels when their newborns were asleep. This suggests that mothers may stay alert and ready to respond even when their babies appear to be resting. Interestingly, among mothers who showed lower stress levels when their babies were sleeping, many reported strong partner support.

We also found that mothers showed the lowest stress levels during breastfeeding. This may be because breastfeeding can release hormones such as prolactin and oxytocin, which help mothers feel calmer and may reduce the risk of postpartum mood challenges.

Our findings suggest that postpartum care should not only focus on the newborn but also support maternal physical recovery. Encouraging partner support, helping mothers get structured rest, and promoting shared caregiving may help improve recovery for mothers while also supporting better infant care.

Keywords: postpartum women, postpartum maternal stress, newborn states, rooming-in care, electrocardiography, heart rate variability

Introduction

Postpartum stress (PPS) is defined as a mother's reaction to an external or internal stressor, managed through adaptive or maladaptive coping mechanisms. PPS is positively correlated with postpartum depression,^{1,2} which shares risk factors such as high life stress, poor social support, and prenatal depression.³ Elevated PPS poses risks for both mother and infant, including neonatal developmental delays and maternal mental health disorders.^{4,5} International evidence reveals that these elevated maternal stress levels and physiological regulatory mechanisms are directly manifested through alterations in biomarkers such as cortisol and heart rate variability (HRV), which in turn negatively influence exclusive breastfeeding outcomes and maternal-infant bonding.^{6,7}

Common PPS triggers, especially for first-time mothers (primiparous), involve frequent newborn crying, health concerns, partner relationship difficulties, and lack of social support.^{8–11} Furthermore, Asian primiparous women face additional socio-cultural and breastfeeding pressures.¹² Beyond these external factors, maternal states, such as fatigue and pain, are potential stressors that may confound the assessment of PPS. Postpartum fatigue has been consistently identified as a core component of the maternal distress burden, showing strong correlations with depressive symptoms and stress in both meta-analytic and longitudinal studies.^{13,14} Similarly, postpartum pain, including childbirth-related and immediate physical discomfort, is associated with increased psychological distress and traumatic symptomatology.¹⁵

Emerging evidence has indicated that newborn neurobehavioral indicators and early behavioral states (e.g., arousal and attention) can significantly correlate with or predict maternal psychological and physiological stress responses.^{16,17} However, current research has neglected to explore the relationship between specific newborn behaviors (i.e., crying, breastfeeding, sleeping, or being held) and maternal stress during the rooming-in period.

To ensure the rigor of our comparison across newborn states, this study also examines whether these observed physiological responses are influenced by maternal fatigue and pain, treating them as critical variables to assess for potential baseline differences among different stress-level categories. HRV serves as an objective and valid physiological tool to assess human psychological stress responses. When an individual encounters psychological or environmental stressors, homeostatic balance is disrupted, triggering a classic autonomic nervous system (ANS) shift characterized by sympathetic activation and parasympathetic (vagal) inhibition. A recent comprehensive review indicated that among various metrics, low-frequency (LF)/ high frequency (HF) ratio (reflecting sympathetic dominance) is one of the most frequently reported indices significantly correlated with stress experiences.^{18,19} Therefore, tracking relative variations in these frequency-domain components provides a rigorous, real-time reflection of maternal situational alertness and autonomic adaptation.

Hypothesis Development: Infant States and Maternal Stress

The impact of infant behavioral states on maternal well-being is multifaceted. Infant crying serves as a primary stressor, significantly increasing maternal emotional distress and perceived stress that persists up to six months postpartum.^{20,21} During the rooming-in period, the urgency of responding to a crying infant often exacerbates maternal exhaustion and severe sleep deprivation.²²

While breastfeeding and holding involve nurturing behaviors, their impact on stress is nuanced. Breastfeeding presents a bidirectional relationship with stress: although oxytocin promotes a calming effect, elevated cortisol from postpartum stressors can impair milk production.²³ Similarly, although skin-to-skin contact (SSC) is known to reduce anxiety,^{24,25} the physical demands of holding remain a form of active caregiving.

In contrast, the infant sleep state provides a period of physiological stability and reduced caregiving demands. Evidence suggests that longer infant sleep duration and fewer mother night awakenings correlate with lower maternal perceived stress,^{20,26} even among mothers with a history of depression.²⁷ Unlike the active demands of crying, breastfeeding, or being held, sleep offers a critical window for maternal recovery.

Based on these behavioral and biobehavioral rationales, we hypothesized that the complete removal of active caregiving demands during infant sleep would shift maternal autonomic regulation toward a state of rest, thereby minimizing objective physiological stress. Thus, we hypothesized that maternal stress levels would be significantly lower when the newborn was in a sleep state compared to the other three states (crying, breastfeeding, and being held).

Although rooming-in is widely implemented to support breastfeeding and maternal-infant bonding, limited research has examined maternal physiological stress responses during rooming-in using objective autonomic measures. To address the limitations of conventional subjective questionnaire-based stress measurement,²⁸ this study adopts a rigorous objective approach. We use HRV, an established physiological measurement of stress,²⁹ measured via portable electrocardiogram (ECG) sensors, which are considered the gold standard for accurate data capture.³⁰

Furthermore, to enhance the internal validity of our findings, we assessed the potential confounding effects of fatigue and pain by comparing maternal fatigue and pain levels in the neonatal states that elicited the highest and lowest normalized low frequency (nLF) responses. This analytical approach allowed us to determine whether differences in physiological stress were independent of maternal subjective fatigue and pain.

Aim

This study aims (1) to examine the association between maternal stress during hospitalization and rooming-in levels, and (2) to investigate the relationship between maternal PPS and newborn states. To achieve these aims, this study evaluates maternal HRV responses across different newborn behavioral states to better understand maternal stress in early postpartum care. We hypothesize that: (1) maternal stress is negatively associated with rooming-in engagement, and (2) the mother's PPS level will be lowest when the newborn is asleep, compared to other newborn states. Understanding these patterns will enable healthcare professionals to provide targeted, proactive postpartum support strategies to reduce maternal stress, optimize maternal recovery, and support successful rooming-in implementation.

Methods

Study Design & Setting

We adopted a prospective repeated-measures observational design with consecutive sampling. This design was specifically selected to capture two distinct layers of maternal physiological stress during rooming-in. First, it allows us to evaluate the longitudinal changes in maternal physiological stress between two postpartum time points: Postpartum Day 1 (T1) and Day 3 (T2). Second, it enables the examination of the relative differences in maternal physiological stress responses associated with various newborn states (sleeping, crying, being held, and breastfeeding) from T1 to T2.

We collected data in the postpartum ward of a northern hospital in Taiwan from January to June 2023. Each participant completed informed consent before participation. Before data collection, the study protocol was reviewed and approved by the Research Ethics Committee of National Taiwan University Hospital (Approval No. 202012271RIPD).

Population and Sampling

The sample size was calculated using G*Power 3.1.9.6³¹ to examine the correlation between newborn states and postpartum stress. A two-tailed point-biserial correlation model was employed, setting the α error rate at 0.05, the statistical power ($1-\beta$) at 0.80, and the effect size at 0.5, resulting in a required sample size of 26 families. Considering a 15% dropout rate based on prior studies,³² the recruitment target was adjusted to 31 families ($26/0.85 = 30.58$, rounded up). Ultimately, 43 families participated in this study.

The inclusion criteria were: primiparous participants (a) 4 to 24 hours after vaginal birth (considering the clearance of exogenous oxytocin and epidural anesthesia); (b) over the age of 18; (c) gestational age of between 37 and 42 weeks; and (d) accompanied by a partner during postpartum hospitalization.

The exclusion criteria included: (a) people with clinical conditions during pregnancy or childbirth, such as coagulation dysfunction, severe placenta previa, or complications during childbirth; (b) fetus or newborn with congenital or acquired abnormalities in the fetus or newborn; or (c) people with cardiac arrhythmias, as irregular rhythms with an R-R interval greater than 0.12 seconds affect HRV results.³³

Among the 236 vaginal birth postpartum women screened, 56 met the inclusion criteria. We measured maternal stress at 2 different time points (i.e., Day 1 [T1] and Day 3 [T2] postpartum) for comparison. Among the 56 individuals who met the inclusion criteria, 11 declined to participate, resulting in a total of 45 participants (80% participation rate). During the study, 2 participants were excluded because their newborns were transferred to a special care nursery on the second day due to jaundice, resulting in a dropout rate of 4%. Thus, 43 participants completed the study. When analyzing maternal HRV on different newborn states, any poor HRV signal detection and incomplete records on newborn states were excluded when examining whether stress levels were associated with various newborn states during rooming-in ($N = 30$). The flowchart is shown in [Figure 1](#).

Measures

Maternal Postpartum Stress (HRV)

We measured maternal stress levels through HRV using a portable ECG device.³⁴ ECG offers much better reliability and validity than photoplethysmography in detecting R–R intervals and reflecting autonomic nervous system activity.^{30,35}

To ensure accurate temporal synchronization between the continuous maternal HRV recordings and specific newborn behavioral states, both data sources were aligned using standardized network time. The internal clock of the ECG device was automatically synchronized with internet time via Bluetooth pairing with the research smartphone. Simultaneously, participants recorded the onset and offset of newborn states using the timestamps from their mobile devices, which were also synchronized with network time. This standardized reference facilitated the precise alignment of physiological data with observed newborn states.

To measure a baseline HRV, at T1, participants were first asked to wear a portable ECG device for 5 minutes while listening to light music in a supine position with their eyes closed.³⁶ Once the baseline had been ascertained, the participants continued to wear the device until the end of the study. Participants were also asked to record the time of newborn states (i.e., crying, breastfeeding, being held by the father or mother, sleeping in a bassinet) during participation (from Day 1 to Day 3). At T2, the participants underwent a further 5-minute HRV test using the same posture and context. Finally, they completed an online questionnaire on basic information.

We adopted the time points in the R–R interval³⁷ and transformed the R–R interval to the frequency domain using the Fourier transform for the spectral analysis.³⁸ The Fourier transform formula and spectral distribution are shown in [Figure S1](#) and [S2](#), respectively.

In frequency domain analysis, significant stress is characterized by a decrease in HF and an increase in LF components, supporting the use of HRV as an objective assessment tool for stress and psychological well-being.³⁹ In this study, we computed the nLF through the formula $LF/(LF+HF)$.^{37,40,41} Since nLF is associated with psychological stress and an increase in sympathetic nervous system activity under high-stress conditions,⁴² it represents a viable indicator where a higher nLF indicates higher stress levels.

To ensure data quality, a mother's nLF data were excluded when there was poor detection of signals from the ECG device or, at the time, any missing record of the newborn's states.

Newborn States

We measured the newborns' states (i.e., crying, breastfeeding, being held by the father or mother, sleeping) using the timesheet completed by the parents. The sheet was developed based on the researcher's clinical observation of the interactive patterns of newborns and their parents during rooming-in. The newborn state recording sheet underwent a formal review by an expert committee to establish content validity. To ensure feasibility and clarity, a pilot test was

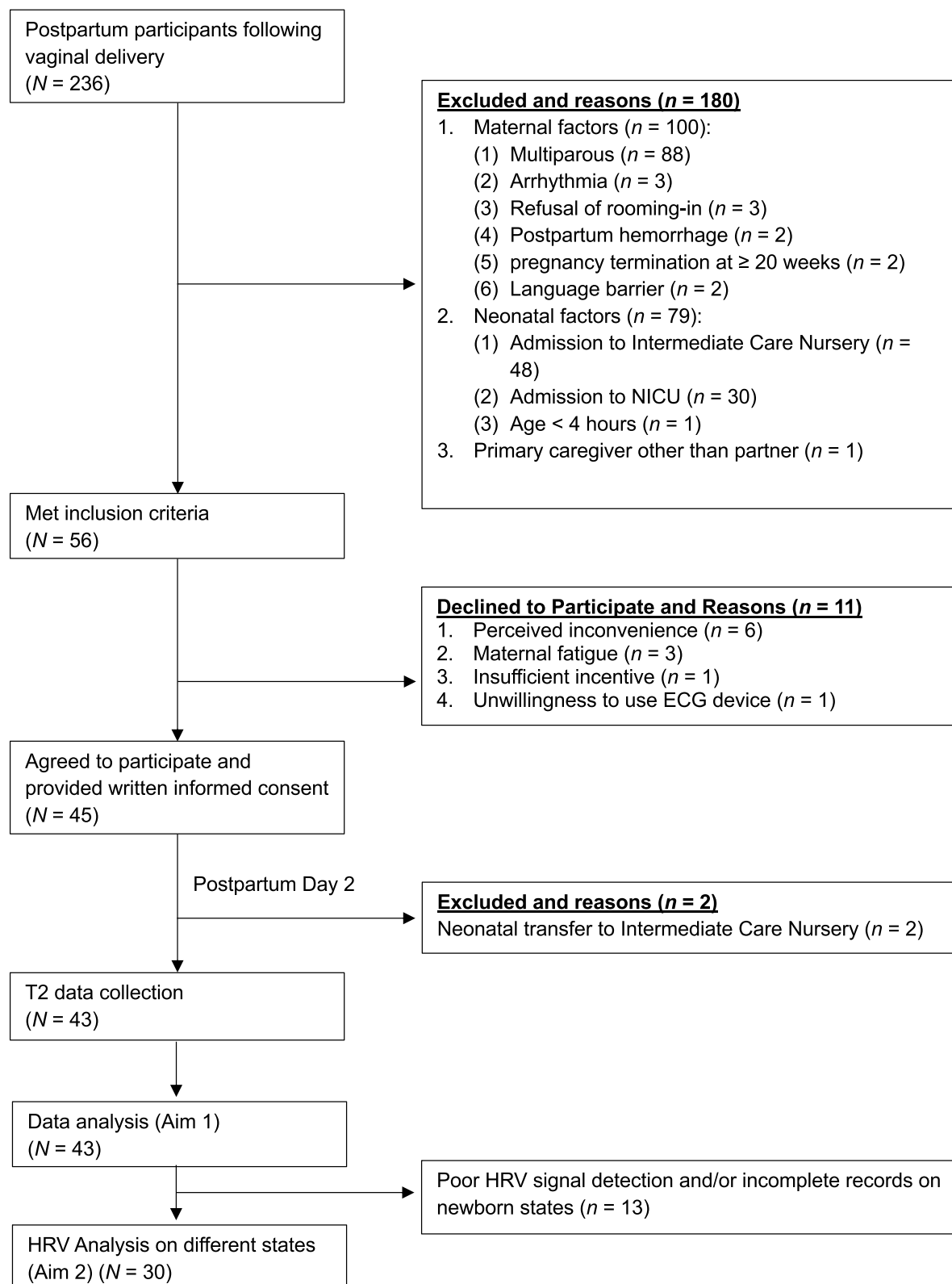


Figure 1 Flow diagram of individual recruitment and enrollment.

Abbreviations: N, total number of screened individuals; n, number of participants in a specific subgroup; PPH, postpartum hemorrhage; SCN, special care nursery; NICU, neonatal intensive care unit; ECG, electrocardiogram; HRV, heart rate variability.

conducted with three postpartum mother-infant dyads before the main study, confirming that the tool was highly usable and that the operational definitions were well-understood by parents. Parents were asked to record the start and end times of each state on the sheet, with a minute as the measurement unit. Time according to the cellphone time. Thus, the HRV window could be synchronized with newborn states. Furthermore, they were requested to note any phenomena meaningful to them. Their notes written on the timesheets were used as contextual references to interpret the quantitative HRV findings.

The operational definitions of the newborn states are: (1) *Breastfeeding*: breastfeeding until when the newborn rests for more than 30 seconds after sucking, remains quiet, and has relaxed elbows. (2) *Being held by parents*: The newborn is held on either the partner's or the mother's chest. (3) *Crying*: Crying that persists for more than 10 seconds without a spontaneous stop. (4) *Sleeping in a bassinet*: The newborn has closed eyes and is not easily awakened.

Levels of Rooming-in

According to the distribution of our rooming-in time data, the 24-hour rooming-in duration was classified into four groups: (1) less than 8 hours, (2) 8 hours or more but less than 16 hours, (3) 16 hours or more but less than 24 hours, and (4) exactly 24 hours.

Fatigue

We used the Fatigue Continuum Form (FCF) to measure fatigue on Day1 as the control variable. The FCF was modified by Pugh⁴³ from the Modified Fatigue Symptom Checklist (MFSC), which utilizes a Likert scale to indicate varying levels of fatigue: 1 = Not at all, 2 = Mild, 3 = Moderate, and 4 = Severe. Possible total scores range from 30 to 120. Higher scores refer to greater fatigue intensity. According to Pugh et al,⁴⁴ a total score of ≤ 38.5 is classified as low fatigue, 38.6 to 64.4 as moderate fatigue, and ≥ 64.5 as high fatigue. Kuo et al⁴⁵ noted that the FCF is an appropriate tool for this study due to its concise response format, which minimizes the burden on participants. Regarding the reliability of this instrument, the Cronbach's α values range from 0.77 to 0.92, indicating high internal consistency.⁴⁶

Pain

Pain is measured using a proxy indicator based on previously experienced breastfeeding issues (specifically nipple pain). The measurement scale assesses the perceived level of difficulty: 1 = No problem, 2 = Mild difficulty, 3 = Moderate difficulty, and 4 = Severe difficulty. Breastfeeding difficulties also included perceived insufficiency of human milk for the newborn, breast engorgement, flat or inverted nipples, newborn latching difficulties, and mastitis.

Demographic and Obstetrics Data

Demographics (i.e., age, education, marital status, intended pregnancy, employment status, and family income) were collected by online self-administered questionnaires. Obstetric data included whether assisted birth and feeding methods were used during hospitalization.

Data Collection

Data collection followed a strict chronological sequence from T1 to T2, with all devices synchronized to network time to ensure precise alignment.

Phase 1: Baseline Assessment (Postpartum Day 1, T1)

Within 4 to 24 hours post-vaginal birth, eligible primiparous women provided written informed consent for study enrollment. Following the setup and Bluetooth pairing of the portable ECG device by the research team, participants underwent a 5-minute baseline HRV assessment while remaining in a supine position with their eyes closed, listening to a standardized track (*Air on the G String* by J.S. Bach).

Phase 2: Continuous HRV Monitoring and Newborn States Tracking (Day 1 to 3)

Following the baseline test, participants wore the ECG device continuously during their hospital stay. Both parents were trained to reapply the device after showering using an illustrated pamphlet, and the research team monitored connectivity

online. Concurrently, parents used a standardized paper timesheet to log the exact start and end times (to the nearest minute) of four newborn states: breastfeeding, being held, crying, or sleeping in a bassinet.

Phase 3: Follow-Up and Study Completion (Postpartum Day 3, T2)

At T2, participants completed a second 5-minute resting HRV test under identical contextual parameters. Finally, participants filled out online questionnaires regarding demographics, obstetric history, FCF, and localized breastfeeding pain.

Signal Processing and Data Alignment

Continuous ECG data were processed into maternal nLF parameters using a 5-minute sliding window with 1-minute increments and then chronologically matched with the newborn state logs. Detailed technical specifications of the ECG hardware and formulas are provided in the [Supplementary Material](#).

Data Analysis

We used the SPSS software version 22.0 for data analysis. Initially, descriptive statistics were employed to summarize the variables. Paired sample *t*-tests were conducted to examine the change in nLF stress level between T1 and T2.

Maternal HRV parameters were calculated using a 5-minute sliding window with 1-minute increments, ensuring a continuous stream of physiological data. These HRV values were then matched to the corresponding time periods in the newborn state record. Given that the parents' recording unit was one minute, the minimum duration threshold for a newborn state episode to be included in the matching analysis was set at one minute.

Maternal nLF data were matched to the newborn state diaries (breastfeeding, crying, being held, and sleeping) using a 5-minute sliding window. Considering HRV metrics are strongly influenced by inter-individual differences and measurement context.⁴⁰ Normative HRV values vary by age, sex, recording duration, and physiological state, and different HRV standards are not interchangeable.^{40,47} To mitigate this confounding effect, we applied a within-subject ranking approach, which allows participants to self-compare against their own baseline and may provide a more robust approach than direct between-subject comparison. Thus, we computed and ranked the average nLF across these four behavioral states from 1 (lowest) to 4 (highest) for each participant.

To examine the association between maternal physiological stress and newborn states, Chi-square tests were performed based on the frequency distribution of participants who exhibited their lowest or highest stress levels in each corresponding state. Originally, we hypothesized that maternal stress levels would be the lowest when newborns were in the sleeping state compared to the other behavioral states.

During the analysis of HRV data, participants with poor ECG signal quality or incomplete newborn state diaries were excluded, yielding a final analytical sample of 30 participants for the newborn states comparison. Furthermore, when evaluating the specific impact of rooming-in, four additional participants were excluded: two who engaged in full rooming-in (leaving no non-rooming-in baseline data) and two who lacked HRV data during the non-rooming-in period. Consequently, a subgroup of 26 participants was analyzed for rooming-in comparisons to ensure data consistency and methodological rigor.

To evaluate the potential confounding effects of maternal physical distress, we conducted a post-hoc analysis comparing fatigue and pain across four types of newborn states for the lowest (ranked 1st) and highest (ranked 4th) maternal nLF categories. We analyzed the maternal fatigue levels across the four types of newborns when mothers' nLF was lowest (or highest) using Kruskal–Wallis tests. For maternal pain, we assessed the distribution of nipple pain difficulties in the four types of newborns when mothers' nLF was lowest (or highest) by Chi-square tests. These analyses aimed to verify whether the observed maternal stress variations were independent of the mother's baseline fatigue and localized pain levels.

Results

A total of 43 participants completed the overall longitudinal follow-up. For the synchronized newborn states analysis, after excluding 13 participants due to poor ECG signal quality or missing timesheet entries, data from 30 participants were successfully analyzed using relative ranking.

Demographic Data

Among the 43 participants, the average (*SD*) maternal age at childbirth was 33.3 (4.03) years. Almost all the participants had an education above college level (98%), and more than half of the participants reported a monthly family income exceeding United States Dollars (USD) 3,000 (54%). Additionally, 58% of participants practiced rooming-in for more than 16 hours per day but less than 24 hours. Just under half of the participants exclusively breastfed (46%). Some of the participants (47%) experienced moderate or severe difficulty with perceived insufficiency of human milk production, as shown in Table 1.

Table 1 Distribution of Basic Information of Participants (N = 43)

Basic Information	M (SD)/ n (%)
Age	33.3 (4.03)
Education	
High school/Vocational school	1 (2)
Bachelor's degree	30 (70)
Master's degree	12 (28)
Marital status	
Married	40 (93)
Unmarried	3 (7)
Intended pregnancy	
Yes	35 (81)
No	7 (16)
Declined to answer	1 (2)
Employment status	
Yes	37 (86)
No	6 (14)
Family income (USD/ month)	
≤ \$3,000	17 (40)
> \$3,000	24 (56)
Declined to answer	2 (5)
Rooming-in level	
< 8 h	0 (0)
≥ 8 and <16 h	14 (33)
≥16 and < 24 h	27 (63)
24 h	2 (5)
Fatigue on Day1 (possible range: 30–120)	54.0 (13.16)
Nipple pain (e.g., cracked or blistered)	
None	13 (30)
Mild	14 (33)
Moderate	13 (30)
Severe	3 (7)
Perceived insufficiency of human milk for newborns	
No problem	10 (23)
Mild	13 (30)
Moderate	12 (28)
Severe	8 (19)
Breast engorgement	
None	18 (42)
Mild	19 (44)
Moderate	5 (12)
Severe	1 (2)

(Continued)

Table 1 (Continued).

Basic Information	M (SD)/ n (%)
Flat or inverted nipples	
None	28 (65)
Mild	10 (23)
Moderate	3 (7)
Severe	2 (5)
Newborn latching difficulties	
None	13 (30)
Mild	14 (32)
Moderate	8 (19)
Severe	8 (19)
Mastitis (including breast abscess)	
None	39 (91)
Mild	3 (7)
Moderate	1 (2)
Severe	0 (0)
Assisted birth	
Vacuum	22 (51)
None	21 (49)
Feeding method	
Exclusive breastfeeding	20 (46)
Mixed feeding (as advised by a physician)	2 (5)
Mixed feeding (as requested by family)	21 (49)

Abbreviation: USD, United States dollars.

Change in Overall Maternal Stress

The overall physiological stress (nLF) showed an increasing trend. Specifically, the mean (SD) nLF at T1 was 52.2 (20.70), while the mean (SD) nLF rose to 61.3 (19.19) at T2, indicating a significant increase in overall stress ($t = 2.38$, $p = 0.022$).

To control for the potential confounding effects of physical symptoms over time, a linear mixed model (LMM) with a first-order autoregressive [AR(1)] covariance structure was adopted. Maternal pain and fatigue scores were entered as time-varying covariates. After adjusting for these concurrent confounders, the fixed effect of time (T1 vs. T2) on overall physiological stress (nLF) remained statistically significant ($F(1, 40.52) = 5.17$, $p = 0.028$). This solidifies that the increasing trend in maternal physiological stress occurred independently of changes in physical pain and fatigue levels.

Association Between Maternal Stress and Rooming-in Level

Pearson's correlation coefficients (r) between maternal stress (nLF) and rooming-in level were 0.05 ($p = 0.778$) and 0.06 ($p = 0.697$) at T1 and T2, respectively, indicating no significant association between maternal stress and rooming-in levels.

To control for the potential confounding factors (i.e., fatigue and pain), partial correlation analysis was performed. After adjusting for maternal fatigue and pain scores, the partial correlation coefficients remained non-significant at both T1 ($r = 0.10$, $p = 0.553$) and T2 ($r = 0.07$, $p = 0.697$), confirming that the lack of associations was independent of these physiological confounders.

Association Between Maternal Stress and Newborn States

Contrary to our hypothesis, when the newborns were asleep during rooming-in, participants experienced the highest nLF stress (65.4% [SD 8.91]). However, when breastfeeding, the nLF percentage was the lowest (60.2% [SD 9.76]; Table 2). Further, the average stress level was only 56.7% (SD 11.06) when they were not rooming in.

Table 2 Comparison of Maternal Stress Variations with Newborn States (N = 30)

Rooming-in		nLF Among Four Newborn States		
		nLF (%)	Lowest	Highest
		<i>M (SD)</i>	<i>n (%)</i>	<i>n (%)</i>
Newborn states rooming-in	30			
Crying		60.3 (11.68)	9 (30)	4 (13)
Breastfeeding		60.2 (9.76)	12 (40)	2 (7)
Being held		60.4 (11.48)	7 (23)	2 (7)
Sleeping		65.4 (8.91)	2 (7)	22 (73)
Non-rooming-in	26	56.7 (11.06)	11 (43)	3 (11)

Note. A total of four participants were excluded from the non-rooming-in group: two due to full rooming-in (resulting in a lack of non-rooming-in data) and two due to incomplete HRV data during the non-rooming-in period. Consequently, data from 26 participants were included in the final analysis for the non-rooming-in condition. The term “lowest” means the count of participants exhibiting the lowest stress in a certain state, as measured by nLF, among all newborn states. Conversely, “highest” means the number of participants experiencing the highest stress levels in a certain state, as measured by nLF, among given newborn states.

Abbreviation: nLF, normalized low frequency.

To control for potential confounding factors (i.e., fatigue and pain), the post-hoc analysis compared fatigue and pain across four newborn states for the lowest (ranked 1st) and highest (ranked 4th) maternal nLF categories. Kruskal–Wallis tests showed no significant difference in the maternal fatigue levels across the four types of newborns when mothers’ nLF was lowest (or highest). For maternal pain, Chi-square tests showed non-significant differences in the distribution of nipple pain difficulties across the four types of newborns when mothers’ nLF was lowest (either for highest). These analyses aimed to verify whether the observed maternal stress variations were independent of the mother’s baseline fatigue and localized pain levels.

Missing Data and Sensitivity Analysis

To evaluate the potential for attrition and selection bias, we compared the baseline characteristics of the excluded participants ($n = 13$, due to poor HRV signal quality or incomplete logs) with those of the included participants ($n = 30$). As shown in [Table S1](#), the two groups did not differ significantly in most demographic or clinical characteristics (all $ps > 0.05$), with the exception of the rooming-in levels ($p = 0.025$). Participants with lower rooming-in levels had a higher rate of HRV data exclusion, suggesting that the missingness mechanism may be missing at random (MAR) rather than missing completely at random (MCAR). This pattern may be attributed to increased maternal physical mobility or varying levels of maternal-infant interaction, which can mechanically affect the signal stability of ambulatory HRV recordings.

To address potential selection bias, we performed a sensitivity analysis using multiple imputation (MI) by IBM SPSS Statistics (version 26.0). The missing HRV values were imputed based on the non-missing demographic and clinical data for 20 iterations, including rooming-in characteristics. The primary statistical analyses were then re-run using the pooled imputed dataset ($N = 43$).

As presented in [Table S2](#), the results of the sensitivity analysis were highly consistent with our original analysis based on complete cases, demonstrating that the systematic missingness related to rooming-in did not significantly bias the primary findings or change the statistical conclusions of this study.

Discussion

This study is the first to utilize portable ECG devices worn by postpartum women to examine maternal physiological stress in relation to various newborn states during hospitalization. Our investigation revealed two key findings: (1) the highest stress levels occurred when newborns were asleep, and (2) maternal stress showed no significant association with

rooming-in level. These findings enhance neonatal and maternity nurses' understanding of situational stress during rooming-in, thereby facilitating targeted interventions and guidance. Our findings highlight that while rooming-in is beneficial for bonding, it can also pose challenges for postpartum women. This phenomenon underscores the importance of prenatal preparation.⁴⁸ Once the postpartum family has parenting skills, the stress during rooming-in may decrease.

Maternal Physiological Stress and the Paradox of Infant Sleep

A key finding of this study is that the greatest physiological stress for the majority of participants (73%) occurred concurrently with the newborn's sleep state. Although it was hypothesized that infant sleep would provide a window for maternal recovery, our objective physiological data revealed a contrary pattern. This unexpected finding demonstrates that infant sleep does not automatically equate to maternal rest; instead, this period is characterized by heightened physiological alertness. Our systematic quantitative findings support the highly contextual nature of maternal stress, as evidenced by a distinct pattern where the highest nLF power, reflecting sympathetic dominance or a situational sympathovagal shift, was observed during the newborn's sleep state. This evidence reframes the understanding of the postpartum rooming-in experience, indicating that the infant's sleep window does not inherently translate into a restorative period for the mother.

To explore potential contextual mechanisms underlying this high-nLF phenomenon, we examined supplementary activity logs on the newborn record (timesheets). These clinical notes suggested a notable behavioral pattern: when the newborn fell asleep, mothers frequently documented a compelling need to immediately complete delayed daily self-care activities (e.g., eating, showering, and toileting). Because direct infant care remained the primary focus during the newborn's waking hours, mothers appeared to utilize these limited sleep windows to rapidly attend to their basic physiological needs. While not analyzed through a formal qualitative research design, these descriptive records provide a plausible contextual explanation; the elevated nLF levels during infant sleep may reflect a state of physiological time urgency, driven by the pressure to complete essential personal tasks within an unpredictable timeframe.

This contextual hypothesis is further illustrated by a distinct contrast observed in a limited subset of our sample ($n=2$), where participants manifested their lowest nLF levels when the newborn was asleep. Interestingly, their activity logs indicated that these low-stress intervals occurred exclusively when the spouse actively assumed infant care, thereby allowing the mothers to engage in undisturbed rest. While these individual observations are descriptive and lack statistical power for generalizing causal inference, this divergence aligned with developmental literature indicating that increased paternal caregiving is associated with more consolidated maternal sleep,^{49,50} suggesting that spousal involvement may play a vital role in facilitating maternal physiological and behavioral recovery. The contextual hypothesis underscores a critical area for future investigation: the potential buffer effect of partner support in relieving maternal sympathovagal shifts during postpartum rooming-in.

The Dual Impact of Breastfeeding on Maternal Stress

Our findings confirmed that 40% of participants exhibited the lowest stress levels during breastfeeding, with an average nLF (*SD*) of only 60.2 (9.76). This physiological relaxation is consistent with the established neuroendocrine pathway of breastfeeding, where the release of oxytocin and prolactin downregulates maternal stress responses.⁵¹ Additionally, a systematic review indicates a correlation between breastfeeding and the mother-infant relationship, with mothers frequently demonstrating positive indicators such as better mother-infant interaction and secure attachment during the breastfeeding process.⁵² Previous studies emphasized that practicing full rooming-in can improve postpartum bonding,⁵³ reinforcing the psychological benefits of breastfeeding that support rooming-in practices.

Conversely, a small subgroup ($n = 2$) reported their highest stress level during breastfeeding. Timesheet notes revealed that these mothers experienced acute physical distress, including severe stinging or cracked nipples, alongside anxiety over infant crying due to perceived milk insufficiency. Prior research has established that such postpartum distress and concerns regarding newborn care are critical risk factors associated with the early cessation or abandonment of exclusive breastfeeding.^{8,9} These findings highlight that while breastfeeding itself promotes physiological relaxation, health professionals should prioritize the early screening and management of lactation challenges, such as nipple pain and perceived milk insufficiency, to prevent exacerbating maternal stress.

Maternal Stress and Rooming-in Decisions: Cultural and Clinical Implications

Contrary to our hypothesis, this study found no significant association between maternal physiological stress and rooming-in levels, suggesting that stress may not be the primary factor driving the refusal of rooming-in care. Current literature suggests that the relationship between maternal stress and rooming-in level is complex. For example, van Veenendaal et al⁵⁴ found that mothers using a family-integrated care model and couplet-care for the mother-newborn dyad reported lower stress levels and higher infant care involvement. More than 90 minutes of daily Kangaroo Mother Care (KMC) reduced maternal stress (cortisol levels) and postpartum depression.⁵⁵ Therefore, family-centered integrated care, especially with increased skin-to-skin contact time, is expected to reduce maternal stress. However, the early postpartum transition presents competing demands for rest and infant bonding.

In Taiwan, postpartum units typically allows mothers flexibility in deciding when to room-in, as newborn nurseries are available. Because of traditional Asian “doing-the-month” practices, many Taiwanese women prioritize physical rest during the postpartum period and therefore prefer to delegate infant care to nursery staff. Understanding these cultural preferences may help international maternity nurses better understand the cultural considerations of Asian populations, particularly those with a Chinese cultural background, and adjust their care strategies to address postpartum stress related to rooming-in.

Balancing the need for rest with the benefits of rooming-in requires effective prenatal education and timely, family-centered postpartum support. Mothers’ prenatal willingness to participate in full rooming-in is associated with postnatal maternal–infant bonding,⁵³ and maternal bonding is related to maternal stress.⁵⁶ Strengthening prenatal education to enhance mothers’ readiness for full rooming-in should therefore be a clinical priority.

Limitation

Several limitations of this study should be acknowledged. First, regarding the baseline HRV measurement, we did not utilize music specifically tailored to individuals’ stress relief. Instead, all participants underwent a five-minute baseline recording in a standard environment with *Air on the G String* by J.S. Bach in the background. This approach was explicitly chosen to maintain contextual consistency across all participants in this study.

Second, the inclusion and exclusion criteria restricted the participants to primiparous women without clinical complications during pregnancy or childbirth. This approach was essential to ensure the integrity of HRV data by minimizing physiological noise, such as arrhythmias or pharmacological interference from complications. It may have resulted in a healthier-than-average postpartum sample. Consequently, the physiological stress variability observed in this study might be underestimated compared to a more clinically diverse postpartum population. Future research should consider including high-risk postpartum groups to explore a broader spectrum of maternal stress responses.

Third, acute hormonal fluctuations (e.g., changes in oxytocin and cortisol) were not directly measured. Although these biomarkers closely modulate postpartum stress, this study prioritized non-invasive, continuous physiological monitoring to minimize disruption to maternal recovery and the rooming-in experience. Future studies could incorporate salivary biomarkers to complement these autonomic findings.

Fourth, because the newborn state measure relied on parental self-recording over a 48-hour window, the inherent risk of recall or reporting bias must be acknowledged. To mitigate this risk, the research team synchronized network time across all devices and provided comprehensive, illustrated training to both parents at enrollment to ensure real-time and precise data logging.

Fifth, due to poor signal quality and incomplete logs, 13 participants were excluded from the final analysis. Methodological evaluation indicated that this missingness was associated with the level of rooming-in (Missing at Random), which may limit the generalizability of the HRV findings to populations with exceptionally low rooming-in performance. Nevertheless, our sensitivity analysis via multiple imputation demonstrated that this attrition did not significantly alter the primary statistical conclusions.

Finally, due to rigorous quality control for physiological monitoring, the analyzable sample size decreased from the initial $n = 43$ to $n = 30$ for newborn states and $n = 26$ for rooming-in comparisons. This attrition compromised the statistical power of higher-order inferential tests (e.g., repeated measures), increasing the risk of Type II errors.

Consequently, these subgroup findings are exploratory rather than confirmatory and should be interpreted with caution. Nevertheless, they provide valuable clinical insights into HRV trends across caregiving contexts, serving as a foundation for future, larger-scale investigations.

Conclusion

This study demonstrates that maternal physiological stress is highly contextual during the early postpartum hospitalization, operating independently of rooming-in levels. Notably, nearly three-quarters of postpartum women experienced their highest physiological stress when the newborn was asleep. Conversely, breastfeeding emerged as the primary context associated with the lowest stress levels, although this benefit remains vulnerable to early lactation challenges. This study provides preliminary exploratory evidence that maternal autonomic activity varies across caregiving contexts, suggesting that maternity health professionals should heighten support during newborn sleep periods and early management of lactation challenges.

Disclosure of AI tool use

The authors acknowledge the use of Grammarly (v1.2.238.1846) for grammar, spelling, and punctuation checking, and ChatGPT free version for improving the clarity and readability of the manuscript. All AI-generated suggestions were reviewed, verified, and edited by the authors, who retain full responsibility for the final content.

Abbreviations

PPS, Postpartum stress; nLF, Normalized low frequency; HRV, Heart rate variability; ECG, Electrocardiogram; HF, High-frequency; LF, low-frequency; USD, United States Dollars.

Data Sharing Statement

The datasets used and analyzed during the current study are not publicly available due to participant privacy and institutional restrictions.

Ethics Approval and Informed Consent

This study adhered to the principles of respect for autonomy, nonmaleficence, beneficence, and justice. Participants were informed about the study's potential benefits, risks, and data handling procedures and were allowed to make an autonomous decision regarding participation. All collected data were treated confidentially to protect participants' privacy. Prior to data collection, the study protocol was reviewed and approved by the Research Ethics Committee of National Taiwan University Hospital (Approval No. 202012271RIPD) and authorized by the Department of Teaching and Research, with the Department of Nursing serving as the executing audit unit. Before the study began, the researchers explained the study's purpose, objectives, and procedures, emphasizing that participation would not affect routine care and that participants could withdraw from the study at any time. Written informed consent was obtained from all participants, and the collected data were anonymized, coded, and strictly used for research purposes only.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declared no conflicts of interest in this work.

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