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Research article

Spontaneous behaviors during breast crawling and factors influencing self-locating mothers' breasts in newborns: A cross-sectional study

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ABSTRACT

Breast crawling in newborns to propel themselves to their mothers' breasts normally occurs upon skin-to-skin contact with mothers immediately after birth but is often missed by the neglect of hospital staff and insufficient evidence support. Hence, this study described the behavioral characteristics of 135 newborns from China during breast crawling and further explored the factors influencing newborns' self-locating mothers' breasts (measured by whether fail to experience the familiarization stage, initial time and duration of the familiarization stage) using multivariable analysis. The findings supported and extended previous studies that newborns could emerge in nine instinctive stages and corresponding spontaneous behaviors early in life. Moreover, abnormal fetal heart rate during labor appeared to interfere with newborns experiencing the familiarization stage (aOR = 9.27, 95% CI: 1.41 to 61.07, $P = 0.021$), while using synthetic oxytocin ($\beta = 5.94$, 95% CI: 0.35 to 11.54, $P = 0.037$), using antibiotics ($\beta = 11.09$, 95% CI: 4.11 to 18.07, $P = 0.002$), and newborns' gender ($\beta = -5.69$, 95% CI: 11.26 to −0.12, $P = 0.045$) would alter the initial time of the familiarization stage. Finally, this study proposes evidence-based strategies to prevent abnormal fetal heart rates and improve medication use.

1. Introduction

Until the 1960s, newborns were regarded as completely immature organisms incapable of prior experience and learning, with their behaviors being controlled by a range of primitive reflexes [1,2]. This view was challenged in 1935 [3], and subsequent seminal work showed that although newborns exhibit a series of spontaneous behaviors, some behaviors can be elicited or attenuated by external

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stimuli [2–6]. An underlying connection may lie between individual differences in neonatal behavior and specific experiences of newborns prior to and during birth [2].

After skin-to-skin contact (SSC) with mothers immediately after birth, newborns can exhibit several complex behaviors and undergo nine instinctive stages, i.e., birth crying, relaxation, awakening, activity, resting, crawling, familiarization, sucking, and sleeping [7,8], which are defined as breast crawling. *The Action Plan for Healthy Newborn Infants in the Western Pacific Region (2014–2020)*, formulated by the World Health Organization Western Pacific Regional Office (WHO/WPRO), recommended comprehensively promoting early essential newborn care (EENC), the core of which involves the initiation of continuous SSC immediately after birth in newborns in stabilized conditions [9,10] to support breast crawling. Breast crawling depends on immediate SSC after birth without disturbance and newborns' coordination of sensory (e.g., auditory, visual, tactile sense and smell), motor, and nervous systems. Therefore, its significance extends beyond the initiation of breastfeeding, possibly enabling early self-regulation of newborns, which is critical for their subsequent adaptive, social, and emotional development [11–13].

Up to now, studies about breast crawling are still in their infancy, and small sample sizes based on various medical settings in different countries have depicted the behavioral characteristics of newborns [8,14,15], providing a reference for healthcare providers. For example, in 2011, Widström et al. from Sweden recorded the behavioral sequences and characteristics of 28 newborns using video recording during the first 2 h, reporting that newborns go through nine behavioral stages when SSC immediately after delivery [8,16]. Later, Dani et al. [15] from Italy conducted a relevant study on 17 mother–infant pairs again, and the results were generally consistent with those of Widström et al. [8]. Furthermore, they also found that some newborns would massage their mothers' breasts with their hands during the active and resting stages, stimulating the release of maternal serum oxytocin. Based on these two studies, Brimdyr et al. [14] evaluated newborns' behavioral characteristics concerning breast crawling in 13 cases from Japan and 11 cases from the USA. By integrating them with data from Swedish and Italian studies, they reported that birth crying and awakening are stages that all newborns experience, and the initial expression of birth crying, relaxation, awakening, activity, and crawling stages are similar in time, suggesting that the newborns' behavioral sequence proposed by Widström is universal to some extent.

However, given the difference in the mode of medical care (e.g., drug use) and a few imperfections (e.g., small sample sizes), the generalizability and certainty of the conclusions might be restricted. Greater attention to inconclusive results concerning behavioral characteristics of newborns during breast crawling from different countries is necessary for comprehensively understanding and protecting the spontaneous behaviors of newborns. Therefore, we carried out a cross-sectional study to describe the behavioral characteristics of newborns in China concerning breast crawling with larger sample sizes and further explore the factors influencing newborns' self-locating mothers' breasts.

2. Methods

2.1. Design and participants

This cross-sectional study was undertaken in a tertiary-level hospital in China from April to December 2021. Mother–newborn pairs were enrolled if the newborns (i) were born naturally, (ii) had a gestational age of 37–42 weeks and a birth weight $\geq$2500 g, (iii) were healthy without congenital malformations and diseases, and if mothers (iv) were willing to breastfeed the newborns, (v) had singleton pregnancies, (vi) had no serious pregnancy complications, (vii) had no mental disorders, and (viii) signed an informed consent form. In addition, mother–newborn pairs that had to be separated after birth (e.g., newborns with a 1- and 5-min Apgar score of $<$8, mothers with postpartum hemorrhage or other complications requiring treatment) and mothers with contraindications to breastfeeding were excluded.

This study was approved and supervised by the Ethic Committee of Women's Hospital of Nanjing Medical University (2020-KY-048).

To guarantee the quality, the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) criteria checklist for cross-sectional studies was followed in this report.

2.2. Procedure

Five researchers trained in EENC procedures and the standard collection and coding methods of behavioral characteristics were responsible for recruiting subjects, supporting breast crawling, and measuring behavioral characteristics or other basic information.

The subjects were recruited before mothers gave birth to ensure the newborns were ready for breast crawling immediately after birth. If they were possibly eligible for study subjects, researcher A introduced the study aims and specific procedure and obtained their consent. Once the newborns were born, mother–newborn pairs were screened and included in the study according to the inclusion and exclusion criteria. In line with EENC, support for breast crawling was provided by researcher B following the three steps below.

2.2.1. Pre-implementation

To ensure that newborns were not disturbed and safe, the environment was strictly kept at a suitable temperature (25°C–26 °C), relative humidity (55%–65%), decibels (no more than 38), and lighting. Then mothers were prepared for their newborns' breast crawling in a comfortable position (i.e., semi-reclining or supine position) and exposed their abdomens. Immediately after birth, the newborns were dried to maintain normothermia, and placed in a prone and lengthwise position with their eyes level with the mothers' nipples. Moreover, newborns' heads should be turned to the side initially for subsequent video recording. The bed rails on both sides were pulled up, and a quilt was placed on the mothers and their newborns to prevent neonatal hypothermia. The first umbilical cord

clamping was carried out after umbilical cord pulsation disappeared.

2.2.2. Implementation

A towel or pillow was placed under each mother's arms to support wrapping the arms around newborns, thus preventing newborns from slipping to the sides. Furthermore, the newborn receiving power for breast crawling was also supported with the mother's hand on their feet, with the other hand on their back. The mother's interaction with the newborn (e.g., whispering to the newborn, touching the newborn) was permissible and encouraged if possible. The newborns were secured by monitoring with a pulse oximeter during breast crawling (if the newborns were in danger, breast crawling was promptly terminated for appropriate treatment). Notably, the security of newborns and keeping them in SSC with mothers for 90 min without disturbance from midwives or any other one should be a high priority.

2.2.3. Post-implementation

As the newborns seem to rely on olfactory cues, washing the mother's breasts needs to be postponed. Not only that, but routine care (the second umbilical cord clamping, vitamin K1 injection, weighing, bathing, etc.) was deferred until the completion of 90 min of breast crawling. If the newborns failed to locate breasts and suck, midwives promoted first breastfeeding after routine care. Once mother–newborn pairs were transferred to the postnatal ward, hospital staff provided care for them according to hospital protocols.

2.3. Data analyses

Concerning behavioral characteristics in newborns during breast crawling, the data were collected and coded using the coincident methods and procedures from all the enrolled newborns.

Immediately after birth, researcher A, trained beforehand, videotaped the procedure using the same Sony camera until 90 min after birth. The shooting angle was directly toward the side of the newborn's face facing, and the video view focused on the newborn's body (including the face) to ensure that the newborn's behavioral characteristics were fully recorded.

Three researchers (C, D, and E) coded behavioral characteristics using a researcher-designed sheet for recording (Supplementary 1), which was compiled in accordance with the nine stages proposed by Widström et al. [8,16]. The sheet had a vertical axis covering nine stages (i.e., birth crying, relaxation, awakening, activity, resting, crawling, familiarization, sucking, and sleeping) with 16 behaviors and a horizontal axis indicating whether the behavior occurred, their initial time and duration. Before coding, three researchers performed precoding with five videos randomly selected, and formal coding began with inter-observer reliability (ICC) of >0.8. Specifically, three researchers independently coded behavioral characteristics in formal coding. If there was a disagreement,

Table 1
Baseline characteristics of mothers, newborns and obstetric.

Characteristics	Category	Overall
Total no. of mother-newborn pairs		135
Mothers		
Mean age at enrollment—yr		30.01 (29.41–30.61)
Degree—no. (%)	Bachelor or none	106 (79%)
	Master or above	29 (21%)
Breastfeeding training—no. (%)	No	64 (47%)
	Yes	71 (53%)
Nipple conditions—no. (%)	Normal	118 (87%)
	Retraction/excessive	17 (13%)
Newborn		
Gender—no. (%)	Male	76 (56%)
	Female	59 (44%)
Mean birth weight—kg		3.35 (3.29–3.40)
Mean birth height—cm		49.91 (49.68–50.14)
Obstetrics		
Mean gestational weeks—wk		39.79 (39.64–39.95)
Parity—no. (%)	1	89 (66%)
	≥2	46 (34%)
Use of epidural analgesia—no. (%)	No	38 (28%)
	Yes	97 (72%)
Use of synthetic oxytocin—no. (%)	No	82 (61%)
	Yes	53 (39%)
Use of lidocaine—no. (%)	No	53 (39%)
	Yes	82 (61%)
Use of pethidine/diazepam—no. (%)	No	115 (85%)
	Yes	20 (15%)
Use of antibiotic—no. (%)	No	111 (82%)
	Yes	24 (18%)
Abnormal fetal heart rate—no. (%)	No	129 (96%)
	Yes	6 (4%)

No., number; yr, year; kg, kilogram; cm, centimeter; wk, week.

they consulted with each other for consensus.

Sociodemographic factors (i.e., age, degree, breastfeeding training and nipple conditions of mothers; and gender, birth weight and height of newborn) and obstetric characteristics (i.e., parity, gestational weeks at birth, use of epidural analgesia/synthetic oxytocin/lidocaine/pethidine/diazepam/antibiotic, and abnormal fetal heart rate [FHR]) were collected by researcher A. The section on mothers was investigated during recruitment, while obstetric variables or information about newborns were gathered after birth, referring to clinical information and checking with the midwives and mothers.

2.4. Statistical analyses

All the analyses were performed using SPSS (Version 25; IBM SPSS Statistics, IBM Corporation, Armonk, NY). Data on categorical variables were presented as frequencies (percentages), while those on continuous variables were shown as means with 95% confidence intervals (CI) or medians with interquartile ranges (IQR), as appropriate for the distribution normality. One-way ANOVA and univariate logistic regression analysis were applied for continuous dependent and categorical dependent variables, respectively, to assess the significance of factors for newborns' self-locating mothers' breasts, with $P < 0.05$ taken as the significance threshold. Factors at the level of $P < 0.1$ on univariate analyses were included in the multivariable analysis for testing the independent influencing factors, and the results were presented as adjusted odds ratios (aORs) or β with 95% CI. In addition, if participants with missing data, they were removed before the analyses.

3. Results

3.1. Sample characteristics

A total of 768 mothers were pre-screened for participation in the study before giving birth. Later, 140 mothers meeting the inclusion criteria were eligible for enrollment through screening immediately after birth. Then three newborns were excluded due to the interruption of breast crawling. Among them, two newborns were taken off their mothers' abdomen for second umbilical cord clamping, while one newborn underwent a suctioning procedure to remove amniotic fluid from his/her throat. Additionally, two mothers, feeling postpartum fatigue, withdrew from the study before completing 90 min of breast crawling. Overall, the study missed 3.6% (<10%) of mother–newborn pairs, and the baseline characteristics of 135 mother–newborn pairs included in the study are presented in Table 1.

3.2. Sequence characteristics of spontaneous behavior of newborns during breast crawling

Table 2 presents the behavioral characteristics of breast–crawling newborns in detail. Overall, 100% of newborns experienced birth crying, with a median initiation time of 0.03 (IQR = 0.52) minutes and a median duration of 1.11 (IQR = 3.23) minutes. 59%

Table 2
Behavioral characteristics of newborns when breast crawling (n = 135).

Behavioral characteristics	Raw frequency n (%)	Initial time–min, median (IQR), or mean (95% CI)	Duration–min, median (IQR)
Birth crying	135 (100%)	0.03 (0.52)	1.11 (3.23)
Relaxation	79 (59%)	1.07 (1.73)	0.42 (1.08)
Awakening	134 (99%)	1.27 (2.30)	3.30 (5.64)
Eyes open	128 (95%)	1.63 (3.49)	–
A gentle movement of the head	120 (89%)	2.20 (3.74)	0.52 (1.40)
A gentle movement of limbs	112 (83%)	2.08 (3.96)	0.70 (1.33)
A gentle movement of the mouth	98 (73%)	3.13 (4.75)	0.71 (1.55)
Activity	135 (100%)	7.35 (9.23)	12.28 (26.26)
Pronounced movement of the head	130 (96%)	8.19 (10.70)	2.35 (3.97)
Pronounced movement of limbs	129 (96%)	7.53 (9.45)	1.78 (3.60)
A hand-to-mouth movement	78 (58%)	13.95 (17.35)	1.50 (3.12)
A hand-to-nipple movement	36 (27%)	20.53 (21.18)	1.42 (3.09)
Look at the mother's breast	25 (19%)	14.03 (13.57)	1.70 (1.95)
Look at the mother's face	28 (21%)	9.49 (17.22)	1.67 (4.25)
Make soliciting sounds	36 (27%)	6.27 (12.43)	0.05 (0.15)
Protrude the tongue	55 (41%)	14.57 (13.43)	0.13 (0.54)
Resting	135 (100%)	3.15 (6.03)	19.30 (17.30)
Crawling	126 (93%)	25.26 (23.76)	34.14 (40.13)
Familiarization	104 (77%)	55.48 (52.52–58.43)	10.47 (17.91)
Make soliciting sounds	55 (41%)	62.95 (58.41–67.49)	0.23 (0.65)
A hand to nipple to mouth movement	72 (53%)	56.14 (52.61–59.67)	5.71 (10.37)
Licking the nipple	84 (62%)	60.14 (56.47–63.81)	3.16 (6.32)
Attach to the nipple	57 (42%)	56.47 (52.69–60.25)	0.50 (1.36)
Sucking	47 (35%)	59.65 (55.76–63.54)	7.59 (17.63)
Sleeping	6 (4%)	77.00 (25.50)	3.24 (11.38)

Min, minute; IQR, interquartile ranges; CI, confidence intervals.

underwent relaxation, and 99% underwent awakening, with median initiation times of 1.07 and 1.27 (IQR = 1.73 and 2.30) minutes and median durations of 0.42 and 3.30 (IQR = 1.08 and 5.64) minutes apart. In addition, 100% exhibited activity, with the experience of looking at their mother's face (21%), making soliciting sounds (27%) et al., and resting. 93% crawled, and 77% reached the familiarization stage with effort accompanied by licking the nipple (62%), attaching to the nipple (42%), etc. Finally, 35% suckled successfully, and only 4% of newborns fell asleep.

3.3. Independent influencing factors of newborns' self-locating mothers' breasts

The familiarization stage reflects newborns' ability to self-locate their mothers' breasts. In univariate analyses, when comparing newborns who failed to experience the familiarization stage and newborns who did, newborns failing to experience the familiarization stage were associated with abnormal FHR (OR = 7.56; 95% CI: 1.31 to 43.46, $P = 0.023$) (Table 3). Concerning the initial time of the familiarization stage, the use of synthetic oxytocin (β = 6.43, 95% CI: 0.54 to 12.32, $P = 0.033$) and antibiotics (β = 11.82, 95% CI: 4.67 to 18.98, $P = 0.001$) caused delays, while no factors would affect the duration of the familiarization stage either before the sucking stage or before the resting stage ($P > 0.05$).

Then the possible influence factors at the level of $P < 0.1$ on univariate analyses were transferred into the multivariable analyses. After adjusting for newborns' birth weight and use of epidural analgesia ($P < 0.1$), newborns with abnormal FHR exhibited increased odds of failing to experience the familiarization stage (aOR = 9.27, 95% CI: 1.41 to 61.07, $P = 0.021$) (Fig. 1a). Concerning the initial

Table 3
Factors independently associated with the stages of Familiarization (n = 135).

Factors	Familiarization			
	Fail or not OR (95%CI)	Initial time β (95%CI)	Duration before sucking β (95%CI)	Duration before resting β (95%CI)
Mother				
Age	1.03 (0.92–1.16)	0.08 (−0.70–0.86)	−0.26 (−0.95–0.43)	−0.66 (−1.69–0.37)
Degree				
Bachelor/none	1	1	1	1
Master or above	1.09 (0.41–2.85)	2.93 (−4.31–10.16)	−1.78 (−8.27–4.70)	−3.69 (−13.30–5.92)
Breastfeeding training				
No	1	1	1	1
Yes	1.12 (0.50–2.52)	−4.32 (−10.20–1.55)	1.99 (−2.96–6.94)	6.60 (−1.56–14.76)
Nipple conditions				
Normal	1	1	1	1
Retraction/excessive	1.47 (0.48–4.57)	5.07 (−4.15–14.30)	0.19 (−8.58–8.95)	5.64 (−6.24–17.51)
Newborn				
Gender				
Male	1	1	1	1
Female	1.51 (0.68–3.39)	−5.52 (−11.45–0.40)¶	2.76 (−2.06–7.58)	1.54 (−7.28–10.35)
Birth weight	1.00 (1.00–1.00)¶	0.00 (−0.01–0.01)	−0.00 (−0.01–0.00)	−0.01 (−0.03–0.00)¶
Birth height	1.21 (0.89–1.64)	0.86 (−1.57–3.28)	−1.65 (−3.37–0.08)¶	−2.85 (−6.62–0.92)
Obstetrics				
Gestational weeks	1.10 (0.70–1.73)	−1.55 (−4.90–1.79)	0.43 (−2.63–3.48)	−1.17 (−5.58–3.24)
Parity				
1	1	1	1	1
≥2	0.49 (0.19–1.23)	−4.36 (−10.42–1.71)	−1.62 (−6.49–3.24)	−1.05 (−10.30–8.20)
Epidural analgesia				
No	1	1	1	1
Yes	2.42 (0.85–6.85)¶	0.43 (−5.95–6.80)	−1.45 (−6.52–3.62)	2.83 (−6.40–12.05)
Synthetic oxytocin				
No	1	1	1	1
Yes	0.68 (0.29–1.58)	**6.43 (0.54–12.32)***	−3.27 (−8.53–1.98)	0.93 (−7.39–9.24)
Lidocaine				
No	1	1	1	1
Yes	0.52 (0.23–1.17)	−1.48 (−7.67–4.71)	−2.76 (−7.63–2.12)	3.47 (−5.57–12.51)
Pethidine/diazepam				
No	1	1	1	1
Yes	0.82 (0.25–2.65)	−1.01 (−9.23–7.20)	−1.13 (−7.63–5.37)	−10.53 (−22.16–1.10)¶
Antibiotic				
No	1	1	1	1
Yes	0.62 (0.20–1.98)	**11.82 (4.67–18.98)****	−1.77 (−10.52–6.98)	−5.72 (−14.84–3.41)
Abnormal FHR				
No	1	1	1	1
Yes	**7.56 (1.31–43.46)***	−10.83 (−32.32–10.65)	−7.25 (−19.17–4.67)	incomparable

¶$p < 0.1$.
*$p < 0.05$.
**$p < 0.01$.
OR, odds ratio.
CI, confidence intervals.

time of the familiarization stage, the use of synthetic oxytocin (β = 5.94, 95% CI: 0.35 to 11.54, $P = 0.037$) and antibiotics (β = 11.09, 95% CI: 4.11 to 18.07, $P = 0.002$), and newborns' gender (β = −5.69, 95% CI: 11.26 to −0.12, $P = 0.045$) were found to be independent factors affecting it (Fig. 1b). Similar to univariate analyses, the duration of the familiarization was free from the influence of any factors investigated ($P > 0.05$) (Fig. 1c and d).

4. Discussion

Our results showed that initiating 90 min of SSC without disturbance immediately after birth in healthy newborns would facilitate nine instinctive behavioral stages and corresponding behaviors in them. Abnormal FHR during labor further contributed to newborns' failure to experience the familiarization stage. Additionally, using synthetic oxytocin and antibiotics, together with the newborns' gender, would alter the initial time of the familiarization stage.

4.1. Sequence expression of spontaneous behavior of newborns during breast crawling

Birth crying, as a sign of vitality, often begins within 1 min after birth to expectorate the amniotic fluid from the airway [17]. In addition, newborns in this stage begin spontaneous breathing with effective cardiac output [18]. Similar to the results of previous studies [8,14,15], all the newborns experienced birth crying within 1 min of birth, lasting 1.11 min in the present study. At this stage, newborns' heads turn slightly to the side to facilitate smooth breathing and drainage of amniotic fluid [19].

Overall, 59% of newborns entered the relaxation stage at a median time of 1.07 min, lasting 0.42 min, similar to the findings of Widström et al. [8]. Relaxation is a protective and comfortable experience for newborns, considering being relieved of pain by the familiar heartbeat of mothers [20] or a 20-fold increase in catecholamine caused by the pressure on the head through the birth canal [21–23]. However, we found that some newborns skipped the relaxation stage, consistent with those reported by Brimdyr et al. [14]. The loss of the relaxation stage may be associated with excessive intervention, e.g., unduly stimulating newborns to cry through vigorous rubbing or massaging. That is to say, if newborns are breathing easily, the stimulation is unnecessary and may prevent them from entering the relaxation stage, suggesting that hospital staff should be fully aware of behavioral characteristics and avoid excessive interference that disrupts behavioral sequences [16].

The awakening stage is the preparation of newborns before reaching the activity stage [16]; 99% of newborns in this study experienced it. The first eye-opening marks the awakening stage [14]; however, seven newborns still closed their eyes, coincident with a report by Brimdyr et al. [14]. They suggested that newborns in the awakening stage without eye-opening may be concerned with factors like bright lights or labor medications; instead, they may show other behavioral features. For instance, successive initiation of a gentle movement of head/limbs/mouth happened at a median of 2.08 min in the present study, consistent with the results of Widström et al. [8].

Newborns in the activity stage start to explore the surrounding environment and prepare themselves for crawling. Our finding that all newborns experience the activity stage was similar to those reported in earlier studies [8,14,15]. As a key to successful sucking, the activity stage was characterized by a stronger rooting reflex, with newborns showing apparent movements of limbs/heads (e.g., massaging, hand-to-mouth movement), protruding the tongue, etc. During this stage, facilitated by mothers' sounds and breasts' color, smell and temperature, newborns react instinctively through the coordination of sensory systems, including auditory, visual, tactile, and smell senses, which might contribute to early neurodevelopment [16].

The resting stage occurs repeatedly and is interspersed with the other eight stages, thus making it more difficult to distinguish from

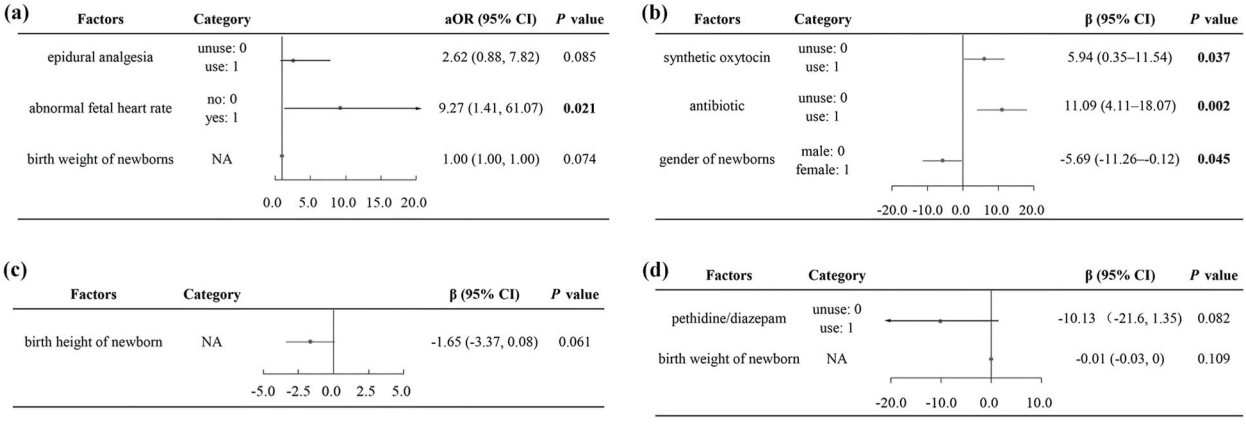

Fig. 1. Forest plot depicting the factors influencing newborns' self-locating mothers' breasts. (a) Adjusted odds ratios of influencing factors for newborns' failure to experience the familiarization stage. (b) Effect sizes of influencing factors for the initiation time of the familiarization stage. (c) Effect sizes of influencing factors for the duration of the familiarization stage before sucking. (d) Effect sizes of influencing factors for the duration of the familiarization stage before resting. aOR and β are represented with a dot; the 95% prediction interval is represented with a bar (aOR, adjusted odd ratio; NA, not appropriate).

brief pauses of behavior [16]. Referring to the point proposed by Brimdyr et al. [14], i.e., pauses in behavior for 15 s could be considered the resting stage, we found that 100% of newborns reached the resting stage first at a median time of 3.15 min, and had a relative reduction or cessation of movement, but could suck fingers accompanied by eye–opening or closing. The resting stage is a period for newborns to relieve fatigue and regain energy [16]. Hospital staff should fully understand the significance of the resting stage for newborns and avoid mistaking the resting stage for poor vitality of newborns, consequently artificially interrupting the familiarization and sucking stages.

The crawling stage can be manifested either as a gentle movement of the body or as a pronounced movement (i.e., propelling the body towards the areola by flexion of the legs), so that changes in position can assist in determining whether to enter the crawling stage [14]. In this study, 93% of newborns experienced the crawling stage that began at 25.26 min and lasted 34.14 min, consistent with the findings of Dani et al. [15]. Nevertheless, some newborns fell to their mothers' sides or slid in the wrong direction, which was not conducive to continuing; therefore, placing a towel or pillow under the mother's arms for support was advisable in clinical practice.

The onset of the familiarization stage is determined by newborns' approaching the areola/nipple [14,16]. 77% of newborns reached the familiarization stage with an effort at 55.48 min, which lasted 10.47 min, similar to previous studies [8,15]. Influenced by the smell and color of the mothers' breasts, newborns familiarized breasts with licking the nipple, subsequently attached to the nipple for first breastfeeding, which not only promoted the release of oxytocin in the mother but also trained the newborns to suck, overtly related to eventual breastfeeding [16]. Notably, if staff artificially assist newborns, most will reject the touch and attach to the nipple again independently. They often slid to one side of the mother's chest to lick the nipple, which is relatively easy for breathing [8].

Overall, 35% of newborns in this investigation successfully reached the sucking stage, different from previous findings of 15%, 55%, and 58%, etc. The difference may arise from several factors, including differences in race, sample size and interventions prior to birth (e.g., intrauterine exposure to synthetic oxytocin or fentanyl) [8,14,15,24]. Most of the mothers in our study received synthetic oxytocin or fentanyl, which may explain the lower probability of reaching the sucking stage. Additionally, newborns in our study spontaneously started to suck 59.65 min after birth. Previous studies indicated that the first 2 h of life is the best time to activate rooting and sucking reflexes, and if missing, the timing of the first breastfeeding will be delayed, and the risk of failure in early exclusive breastfeeding associated with passive breastfeeding will increase [16,25]. Therefore, it is suggested that the hospital staff should appreciate the first independent breastfeeding of newborns during breast crawling and give newborns sufficient time before passive breastfeeding.

Sleeping constitutes the main state of newborns [26]. Normally, newborns fall asleep between 1.5 and 2 h after birth [27], possibly through two mechanisms. First, a high level of cholecystokinin, triggered by the stimulation of prolactin produced during lactation, will relax newborns and help them go to postprandial sleep [28]. Moreover, after undergoing birth stress, newborns need to sleep, which is integral to their recovering and promoting early neurodevelopment as a self-protection behavior [29]. In this investigation, six newborns fell asleep during the 90-min observation, consistent with the findings of Widström et al. [8], but different from other studies [14,15]. Such variability might be due to differences in observation times. Furthermore, the time to the initiation of the sleeping stage in this study was not yet representative since further tracking of other newborns entering the sleeping stage was lacking.

4.2. Abnormal FHR as a factor preventing newborns from experiencing the familiarization stage

Newborns with abnormal FHR during labor exhibited an increased risk of failure to locate breasts in this study. Clinically, abnormal FHR signifies the possibility of intrauterine hypoxia, believed to impact locating the breasts by two mechanisms: (i) lowering the vitality of newborns and leading to a delay in the crawling stage, which subsequently affects the breast-locating behavior, as revealed by Widström et al. [8]. (ii) Fetal defensive reflexes caused by intrauterine hypoxia will redistribute blood, reducing intestinal blood flow and resulting in abnormal intestinal motility and hormonal disruptions, thus causing feeding intolerance or breastfeeding resistance [30,31]. In addition, such newborns often have lower needs for feeding, which may explain the higher risk of failing to locate breasts. All the above suggests the necessity of detecting and improving abnormal FHR.

4.3. Initial time of the familiarization stage varied in newborns with different gender

Concerning the initial time of the familiarization stage, the results showed that the female sex was significantly associated with a slightly earlier initial time, which was the first finding to the best of our knowledge. This might be because familiarization relies on stimuli such as mothers' more pigmented nipples or smell from Montgomery secretions [32], which might have sex differential reactivity. Previous studies indicated that females were superior to males in recognizing smell, taste, and color [33,34], but males were better at sound localization [35]. This suggests that the above advantage in sensory ability may be innate, existing from infancy, so that female newborns locating mothers' breasts were faster than males. Notably, the above is speculation undoubtedly, and further exploration is required to determine whether the difference in advantage exists in children or even newborns and the developmental mechanisms by which female newborns start the familiarization stage faster than male newborns.

4.4. Common labor drugs delayed the initial time of familiarization stage

Synthetic oxytocin is commonly used before delivery in China. However, this considerably delayed the initiation of the familiarization stage, which was similar to that of Brimdyr et al. [36]. Although some studies have shown that oxytocin can enhance olfactory exploration and recognition of adult rats [37,38], exogenous oxytocin could not readily cross the blood-brain barrier (BBB) during labor, with only up to 1.3% of them acting on oxytocin receptors expressed in the central nervous system in adults rats [39,40].

Hence, even though a little synthetic oxytocin passes the placenta and fetal BBB during labor [24,41], the effect on the olfactory response of newborns for promoting newborns' locating mothers' breasts is presumably minimal or nonexistent, given differences in dose and species [42]. Additionally, due to negative feedback mechanisms, central oxytocin levels may decrease, causing lower olfactory responses [43]. Moreover, synthetic oxytocin significantly affects mothers, causing uterine tachysystole, and thus potentially adversely impacts the newborns, like an impaired gas exchange, hypoxia, and abnormal FHR, with potential effects on newborns' locating mothers' breasts [36,43].

In addition to synthetic oxytocin, antibiotics are also used a lot before delivery by women at risk of infection (e.g., with premature rupture of membranes more than 12 h), which also slowed down the process of locating breasts. This might be explained by the disruption of the gut microbiota or other microbiomes in the fetal or neonatal stage by antibiotics through the amniotic fluid or the placenta barriers [44,45]. According to previous studies, the contribution of gut microbiota or other microbiomes to modulating early-life programming of the brain and behavior has been reported [44]. However, it is not clear how they impact newborns' sensory systems thus affecting newborns' locating mothers' breasts, necessitating further explorations.

Nevertheless, we did not find that epidural analgesia, as another common drug, is related to newborns' self-locating mother's breasts, which was assumed an unexpected finding, different from the studies by Widström et al. [8] and Brimdyr et al. [36]. In Widström's study, exposure to meperidine was associated with increased time to reach the familiarization stage [8]. Simultaneously, Brimdyr et al. confirmed that the intrapartum amount of exposure to epidural fentanyl would decrease the possibility of newborns' sucking during the first hour after birth [36]. In response to this controversy, we believe it is impossible to rule out differences caused by dose, dosing interval, and drug metabolism, given that the above elements differ in individuals.

4.5. Limitations and future directions

Some limitations merit discussion. Firstly, the study conducted in a tertiary-level hospital may restrict the generalizability of our findings but complement those of previous studies. Secondly, it was too one-sided for our study to explore the use of common labor drugs alone while ignoring the effects of variability in drug doses, dosing intervals, drug metabolism, etc. Finally, further studies on the association between them could help understand whether there is a correlation and the specific mechanisms between drugs and newborns' self-locating mothers' breasts.

5. Conclusion

When breast crawling, newborns can experience the nine stages, i.e., birth crying, relaxation, awakening, activity, resting, crawling, familiarization, sucking, and sleeping, to varying degrees. Further, risk factors of newborn experiencing the familiarization stage, namely abnormal FHR, was proposed in this study, and the use of synthetic oxytocin, antibiotics, and newborns' gender affected the initiation of the familiarization stage. In consequence, noting the influencing factors involving common drugs and abnormal FHR, attention should be directed to this group, along with evidence-based strategies to prevent abnormal FHR and improve medication use for better development of newborns in early life.

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Author contribution statement

Aixia Zhang; Zhu Zhu: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper. Shengnan Cong: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper. Xuemei Fan; Ping Yu; Lingzhi Wang; Chunxiu Zhou; Rui Wang; Xiaowei Song; Jingyi Feng; Xiaoqing Sun; Lijuan Sha: Performed the experiments; Analyzed and interpreted the data; Contributed materials or analysis tools.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2023.e16440.

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