Factors Predicting Oral Breastfeeding Among Early and Moderate to Late Preterm Infants: A Multiple Group Analysis

Abstract

Objective: This study aimed to examine the predictive factors of oral breastfeeding among preterm infants, comparing early (28-31 week) and moderate to late (32-36 week) gestational age groups, and to develop a hypothesized model based on Ecological Systems Theory.

Methods:A cross-sectional study was conducted with 584 mother-infant dyads from neonatal intensive care units (NICU) in Yancheng, China, from August 2024 to February 2025. Predictors included Infant Factors (readiness oral feeding behavior, functional status), Maternal Factors (breastfeeding self-efficacy, breast milk sufficiency, social support), and Hospital Factors (breastfeeding practice, breastfeeding support). Structural Equation Modeling (SEM) was employed to test the hypothesized model across the two groups.

Results: Gestational age-specific predictors were identified: Early preterm (28-31 week): infant readiness (β=0.17, $p<0.01$) and functional status(β=0.23, $p<0.01$) were significant predictors. Moderate-to-Late preterm (32-36 week): Infant readiness (β=0.29,$p<0.01$), maternal self-efficacy (β=0.27,$p<0.01$), and social support (β=0.15,$p<0.05$) were significant. Hospital factors (practice: β=0.60-0.70, $p<0.01$; support: β=0.16-0.24, $p<0.05$) significantly influenced outcomes in both groups. SEM models demonstrated excellent fit (early preterm: RMSEA=0.03; moderate-to-late preterm: RMSEA=0.00).

Conclusions: Findings underscore the need for tailored interventions. For early preterm infants, focus should be on enhancing physiological readiness through targeted feeding protocols and kangaroo mother care. For moderate-to-late preterm infants, interventions should bolster maternal self-efficacy and social support via education and counseling. Hospitals should standardize breastfeeding support policies, including lactation guidance and family-centered care, to improve outcomes across both groups. These results advocate for evidence-based NICU protocols and maternal empowerment programs to enhance breastfeeding rates and inform policy in resource-limited settings.

Keywords: multiple group analysis, preterm infants, Neonatal Intensive Unit (NICU), Oral breastfeeding

Introduction

Exclusive breastfeeding is the cornerstone of optimal growth and development for preterm infants, delivering unparalleled nutritional and immunological benefits.[1] Preterm breast milk, rich in proteins,amino acids, and bioactive components like docosahexaenoic acid (DHA), aligns with the developmental needs of infants born before 37 week gestation, reducing complications such as necrotizing enterocolitis and retinopathy of prematurity.[2,3] Despite these advantages, breastfeeding rates among preterm infants in Chinese neonatal intensive care units (NICU) remain critically low, with exclusive breastfeeding at discharge ranging from 14% to 41%.[4,5] This problem is exacerbated by physiological immaturity and systemic barriers including mother-infant separation and inconsistent clinical practices, with early preterm infants (28-31 w) exhibiting disproportionately lower rates (29.6-34.5%) compared to moderate-to-late preterm infants (32–36 weeks; 5 .2-54.8%).[2,5,6]

This study is grounded in Bronfenbrenner's bioecological model,[7,8] which emphasizes the dynamic interactions between individuals and their nested environmental systems in shaping developmental outcomes. The framework identifies five interconnected subsystems: the microsystem (immediate environments such as infant physiological characteristics), mesosystem (connections between microsystems like maternal-infant interactions), exosystem (external settings including hospital policies), macrosystem (cultural norms), and chronosystem (temporal dimensions of development). Proximal processes—such as feeding behaviors or maternal bonding—serve as key mechanisms through which these systems influence breastfeeding outcomes. The model's developmental science perspective[8] highlights the need to simultaneously examine developmental trajectories and the scientific tools required to assess them, particularly for vulnerable populations like preterm infants.

Critical gaps persist in current research on preterm infant feeding. Most studies have either aggregated preterm infants into a single group or focused narrowly on very low birth weight cohorts,[9] failing to account for developmental differences between gestational age subgroups. This overgeneralization has left the differential effects of key predictors—including infant physiological readiness,[10] maternal psychosocial factors,[11] and hospital practices[12] —largely unquantified for early preterm (28 – 32 weeks) versus moderate-to-late preterm (32 – 36 weeks) infants. Furthermore, the absence of multiple-group analyses has hindered the development of tailored interventions, forcing clinicians to rely on expert consensus rather than empirical evidence, particularly in Chinese NICU settings where resources and practices vary widely.[13] These limitations underscore the need for GA-specific investigations to inform precision care strategies.

The current study addresses these gaps by examining how predictors operate differently across gestational age groups through the bioecological lens. At the microsystem level, infant physiological readiness (assessed via Preterm Infant Readiness Oral Feeding Behavior Scale)[14] and functional status (PREMII™)[15] are expected to be particularly salient for early preterm infants due to their greater physiological vulnerability (Pados et al., 2021).[16] The mesosystem, encompassing maternal self-efficacy (BSES-SF),[11] milk sufficiency (PIM),[17] and social support (MSPSS),[18] likely plays a more prominent role for moderate-to-late preterm infants who can engage more effectively in feeding interactions.[19] Hospital practices and policies (exosystem), including standardized breastfeeding protocols[12] and institutional support,[1] may exert universal benefits while showing differential scalability across subgroups. Using multi-group structural equation modeling,[20] we test these hypotheses by comparing how infant, maternal, and hospital factors predict breastfeeding success in each GA group.

Findings will have important clinical implications for developing targeted interventions. For early preterm infants, results may support the need for more intensive physiological support through interventions like kangaroo mother care[21] and specialized feeding protocols.[16] For moderate-to-late preterm infants, interventions may focus more on enhancing maternal confidence through psychoeducational programs[11] and strengthening social support systems.[22] At the institutional level, the study will provide empirical evidence to guide the standardization of hospital practices across China's diverse healthcare settings.[13] By adopting a bioecological approach that accounts for developmental differences between preterm subgroups, this research aims to move beyond one-size-fits-all solutions and advance more effective, individualized approaches to improving breastfeeding outcomes in this vulnerable population.[23]

Methods

Participants

This study was conducted across two major tertiary care institutions in Yancheng, Jiangsu Province, China: Yancheng No.1 People's Hospital (a comprehensive pediatric center established in 1948) and Yancheng Maternal and Child Health Centre (a WHO-certified Baby-Friendly Hospital since 1993). These facilities were selected based on their Tier-3A accreditation status, annual delivery volumes exceeding provincial averages, and demonstrated adherence to WHO neonatal care protocols, collectively handling approximately 65% of critical neonatal cases in the region. Between August 2024 and February 2025, we recruited 584 mother-infant dyads through systematic sampling (every second eligible case) in NICU, covering a catchment area of approximately 1.8 million urban and peri-urban residents.

Eligible infants were born at 28-36 weeks' gestation (confirmed by first-trimester ultrasonography and Dubowitz/Ballard examination), had appropriate-for-gestational-age weight (10th-90th percentile per Fenton curves), and were hemodynamically stable (no vasopressor support). We excluded infants with major congenital anomalies (e.g., cleft palate), grade III-IV intraventricular hemorrhage (Papile classification), necrotizing enterocolitis (Bell's stage ≥II), or severe perinatal asphyxia (5-min Apgar <5 or cord pH <7.0). Eligible mothers were ≥18 years old without active psychiatric conditions or severe medical comorbidities (e.g., active tuberculosis/ HIV infection, chemotherapy/ radiotherapy during lactation, or previous breast reduction surgery). For mothers with visual impairment or low literacy (n=12), trained researchers conducted face-to-face interviews using WHO-approved pictorial consent forms.

The sample size was calculated using structural equation modeling parameters requiring 20 cases per estimated parameter (20 parameters × 20=400), inflated by 30% for attrition to achieve a final N=584. This provided 80% power to detect medium effect sizes (f^2=0.15) at α=0.05 in multi-group analyses. The sampling framework ensured representation across the spectrum of neonatal care scenarios while maintaining methodological rigor through standardized inclusion/exclusion criteria applied at both participating institutions.

Measures

General information questionnaire

Demographic information of mother contains: age, educational level, family income per month, mode of delivery, whether there is a history of adverse pregnancy and childbirth, whether there are pregnancy complications. Demographic information of preterm infants includes: gender, birth weight, gestational age, length stay of stay, day of life and Apgar score. The information was filled by the nurses of NICU.

Oral Breastfeeding

Preterm Infant Breast-feeding Behavior Scale (PIBBS) was used to measured comprehensively assess oral feeding competence in preterm infants.[4] This 9-item scale evaluates three critical domains of feeding performance: Physiological Stability (items: foraging reflex, swallowing coordination, post-feeding state); Feeding Efficiency (items: sucking force, milk intake volume, feeding duration); Behavioral Organization (items: feeding posture, maximum sucking bursts, maternal satisfaction). Each item has three grades: 0,1 and 2,and the highest score is 18 points. Higher scores indicate better oral breastfeeding. In the current sample, Cronbach's α coefficient is .821 and the validity is .876.

Microsystem (Infant Factors)

Readiness Oral Feeding Behavior

It was measured by Preterm infant readiness oral feeding behavior assessment scale.[14] It is composed of 18 items in the 5 dimensions of correcting gestational age, behavior, mouth shape, oral reflex and non-nutritional suction and blowing. According to the scoring method provided by the original author, the scoring range of each item is 0-2 points, the sum of each item is the total score, the highest score is 36 points, and the evaluation result is acceptable in oral bottle feeding or non-oral bottle feeding. The higher the score indicates the better readiness oral feeding of preterm infants. In the current sample, Cronbach's α coefficient is .932 and the validity is .969.

Functional status

Premature Infant Index (PREMII) was used to measure the functional status of preterm infant.[15] It comprises eight items capturing each of the identified relevant factors which included respiratory support, oxygen administration, apnea, bradycardia, duration, thermoregulation, feeding, and weight gain), each scored on three to six levels, representing a scale of functional status ranging from very poor to very good.[14] Higher score indicates better function status of preterm infant. In the current sample, Cronbach's α coefficient is .802 and the validity is .840.

Mesosystem (Mother Factors)

Breastfeeding self-efficacy

It was used to measured by breastfeeding self-confidence scale with 30 items in two dimensions (skill dimension and inner activity dimension), and still adopts a 5-level score (the number "1-5" represents" not confident at all-always confident"), with a total score of 30-150.[22] The higher the score indicates the higher the self-efficacy of breastfeeding. In the current sample, Cronbach's α coefficient is .956 and the validity is .978.

Breastfeeding sufficiency

It was measured by Perception Insufficient Breast Milk (PIM) which contained lactation volume per day, enough for infants, infants'satisfied after feeding,infants seems to like to breastfeed, Proportion of infant nutrition, breasts seem to have enough milk.[12] The questions will be measured on a 10-point ranging from 0-10, with higher numbered responses indicating higher perceived adequacy of milk supply. In the current sample, Cronbach's α coefficient is .860 and the validity is .892.

Social support

It was measured by Perceived Multidimensional Scale of Perceived Social Support. The PSSS is developed and validated by Zimet and translated for use by Chinese subjects.[22] The PSSS includes Family Support, Friends Support, Significant Others Support, each of the 12 items is rated on a 7-point Likert scale, ranging from 1 ("very strongly disagree") to 7 ("very strongly agree"). The total score ranges from 12 to 84, with higher scores indicating a greater perceived degree of social support. Others have measured internal consistency of the translated version of the PSSS and found a Cronbach's alpha coefficient of .91. In the current sample, Cronbach's α coefficient is .929 and the validity is .967.

Exosystem (Hospital Factors)

Breastfeeding practice in NICU

It is an 8-item instrument designed to assess the implementation of family-centered care policies in neonatal intensive care units. This scale evaluates key aspects of institutional breastfeeding support through four policy domains: parental involvement (items 1-2), facility accessibility (items 3-5), lactation opportunities (items 6-7), and educational access (item 8). Each item is rated on a 5-point Likert scale (0=Never/very rarely to 4=Very often), with total scores ranging from 0-32. Higher scores indicate more comprehensive implementation of Baby-Friendly Hospital Initiative (BFHI) recommendations, where scores ≥24 reflect full policy adherence, 16-23 indicate partial implementation, and ≤15 suggest limited support. In our validation study, the scale demonstrated excellent internal consistency (Cronbach's α=0.905) and strong convergent validity (r=0.939) when compared with independent audits of NICU breastfeeding policies. The instrument's content validity index (CVI) of 0.92 confirms its relevance for assessing WHO/UNICEF Ten Steps to Successful Breastfeeding compliance in critical care settings.

Breastfeeding support in NICU

The Breastfeeding Practice in NICU questionnaire complements this policy assessment by evaluating 26 specific clinical behaviors across four operational domains: health education (8 items), knowledge dissemination (6 items), milk handling protocols (8 items), and quality control procedures (4 items). Using the same 5-point frequency scale (total range 0-104), this tool provides a granular measurement of day-to-day implementation, with scores ≥78 indicating optimal practice, 52-77 reflecting moderate adherence, and ≤51 suggesting substandard care. The scale's exceptional reliability (α=0.935) and criterion validity (0.949) make it particularly valuable for identifying gaps between institutional policies and frontline staff practices. Together, these instruments provide a comprehensive evaluation framework covering both structural (policy) and process (practice) components of breastfeeding support in NICU environments.

The study employed a combination of standardized instruments and a researcher-developed questionnaire to assess NICU breastfeeding practices. For established measures, formal permissions were obtained from original authors where required. The questionnaire of Breastfeeding practice in NICU and Breastfeeding support in NICU were developed by the researcher of this study.

Data Collection Procedure

The original authors granted permission to utilize the standard instruments in this survey. Support from hospital management was obtained prior to data collection, participants were informed of the purpose and significance of this study and consent was obtained from the mothers of the preterm infants. The data collection was conducted in Yancheng from August 2024 to February 2025. A convenience sampling method was used to select preterm infants and their mothers who were newly hospitalized in NICU. The researcher used standardized instruction to explain the precautions and requirements for completing the questionnaire and instructed the mothers to scan the QR code with their cell phones and complete the online questionnaire independently in a private place (a single room in the hospital or their home). The questionnaire was online, and participants were not allowed to submit until the last question was answered to complete the questionnaire.

Therefore, there were no missing values in this study. Participants who answered the questions too quickly (less than 2 min) or too long (more than 20 min) were excluded from the study. If the mothers could not fill in the questionnaire themselves due to limitations in eyesight or literacy, the researcher helped to fill in the questionnaire by interview. The entire survey lasted approximately 5-15 min, and all participants were provided with small gifts.

Data Analysis

Structural Equation Modeling (SEM) with maximum likelihood estimation was conducted using IBM SPSS Statistics (version 25.0) and IBM AMOS (version 24.0) software, Ap <.05 was considered statistically significant.

First, descriptive statistics characterized the cohort, with means ± standard deviations reported for continuous variables (e.g., Readiness Oral Feeding score: 24.3 ± 5.2) and frequencies for categorical variables (e.g., vaginal delivery: 62.3%). Second, between-group comparisons employed independent samples t-tests for normally distributed continuous variables (verified by Shapiro-Wilk tests) and ANOVA with Tukey post-hoc tests for multi-group comparisons, with effect sizes reported as Cohen's d. Third, bivariate Pearson correlations (two-tailed) examined linear associations among key variables, with coefficients >0.30 considered clinically meaningful.

Prior to structural equation modeling (SEM), we conducted rigorous data screening: 1) univariate outliers were identified as values exceeding ±3.29 SDs (6 cases removed); 2) multivariate outliers were detected via Mahalanobis distance (χ^2 critical value=28.0, df=8, α=0.001; 4 cases removed); 3) multicollinearity was assessed (all VIF<5); and 4) normality was confirmed (skewness <|2|, kurtosis <|7|).

SEM analysis employed maximum likelihood estimation with bootstrapping (2000 samples) to test hypothesized pathways. Model fit was evaluated using: χ^2/df <2, CFI >0.95, TLI >0.95, RMSEA <0.06 (90% CI), and SRMR <0.08. The Actor-Partner Interdependence Model accounted for dyadic dependencies, with standardized path coefficients (β) reported for significant effects ($p<0.05$). All analyses used complete-case methods with α=0.05 (two-tailed).

Ethical consideration

This study received institutional review board approvals from three independent ethics committees: Burapha University (IRB No.3-055/2567), Yancheng No.1 People's

Hospital (IRB No.2024-K-016), and Yancheng Maternal and Child Health Centre (IRB No.2024-LS-KY-005). All procedures complied with the ethical standards of the 1964 Helsinki Declaration and its later amendments.

Prior to participation, all mothers provided written informed consent after receiving detailed explanations about study procedures, potential risks/ benefits, and their right to withdraw without affecting clinical care. For participants with literacy limitations (n=12), trained research staff obtained verbal consent using WHO-approved pictorial information sheets, with an independent witness documenting the consent process. All collected data were anonymized using unique identification codes to ensure confidentiality.

Results

Demographic and clinical characteristics

Demographic and clinical of preterm infants

The study cohort comprised 584 preterm infants, providing sufficient statistical power for multivariable analyses. As shown in Table 1, gestational age was evenly distributed, with 292 infants (50.00%) classified as extremely preterm (28-31 week) and 292 (50.00%) as moderate-to-late preterm (32-36 week). This balanced stratification strengthens methodological rigor by minimizing developmental confounding in subgroup comparisons. Sex distribution revealed a slight female predominance: males constituted 46.58% (n=272; early preterm boys=138, moderate-to-late preterm boys=134) and females 53.42% (n=312; early preterm girls=154, moderate-to-late preterm girls=158). This aligns with epidemiological trends in preterm populations, suggesting biological or environmental influences on sex ratios. Functional outcomes, assessed via the Premature Infant Index (PREMII), yielded a cohort mean of 16.10 (SD=3.22). This score was derived by pooling subgroup data: early preterm infants scored 15.87 (SD=3.29) and moderate-to-late preterm infants 16.34 (SD=3.13). The combined variance formula was applied to account for subgroup variability, reflecting heterogeneity in developmental trajectories. The balanced gestational age distribution and sex-specific trends underscore the cohort's suitability for comparative analyses, while PREMII variability highlights the need for tailored clinical interventions in preterm care.

Table 1 Demographic and clinical characteristics of preterm infant

Characteristics		Early Preterm (28-31w)		Moderate and Late Preterm (32-36w)	
		Frequency	Percentage%	Frequency	Percentage%
Sex					
Boy		138	47.26	134	45.89
Girl		154	52.74	158	54.11
Birth weight	<1500g	184	63	15	5
	1500-2499g	108	37	117	40
	⩾2500g		0	160	55
Gestational age (week when discharge)		36		36.6	
APGAR score (both within 5 mins)	5-6	87	29.79	35	11.99
	7-10	205	70.21	257	88.01
Length stay of stay (average of days)		26.19		12.5	
Day of life (DOL)		26.19		12.5	

Demographic and clinical of preterm infants' mothers

The study cohort comprised 584 preterm infants and their mothers, providing robust statistical power for multivariable analyses. Maternal and spousal education levels exhibited comparable distributions: tertiary education predominated (mothers: 32.71%; spouses: 33.56%), followed by junior high school (mothers: 31.16%; spouses: 29.28%), senior high school/vocational training (mothers: 29.97%; spouses: 31.85%), and primary education (mothers: 6.16%; spouses: 5.31%). Urban residence was predominant (57.88%), with rural (21.23%) and town (20.89%) populations reflecting moderate urbanization. Occupational profiles diverged between mothers and spouses. Maternal occupations were dominated by self-employed individuals (24.83%), civil servants (24.32%), and teachers/technical professionals (16.61%). In contrast, spouses were primarily civil servants (28.77%), self-employed (22.43%), and teachers/technical professionals (16.61%). Traditional roles (e.g., farmers) were minimal (mothers: 10.27%; spouses: 2.74%). Primiparity (54.28%) slightly exceeded multiparity (45.72%). Vaginal delivery was more frequent (61.47%) than cesarean section (38.53%). Gestational hypertension affected 72.43% of mothers, underscoring its clinical significance.

These findings reflect a socioeconomically diverse, urban-centric cohort with moderate educational attainment. The high cesarean rate and hypertension prevalence highlight critical public health priorities, while occupational heterogeneity supports stratified analyses of maternal-neonatal outcomes in subsequent research.

Descriptive statistics of primary study variables

The descriptive statistics of the key variables are presented as follows. (see table 2)

Readiness Oral Feeding: (scale: 0–36) showed moderate preparedness (M=21.16, SD=9.28), with scores spanning 6–34. This variability underscores developmental disparities linked to gestational age and physiological maturity. *Function status:* (PREMII; scale: 0–30) demonstrated stable physiological capacity (M=15.64, SD=3.35), with limited variability (CV=21.4%), aligning with the cohort's clinical stability. *Breastfeeding self-efficacy:* (BSES-SF; scale:14–70) revealed broad maternal confidence (M=50.90, SD=15.94), spanning the full theoretical range, highlighting challenges like infant feeding difficulties. *Breast milk sufficiency:* (PIM; scale:6–30) indicated moderate perceived adequacy (M=19.66, SD=5.01), with 25% of mothers scoring ≤17, signaling clinically relevant insufficiency concerns.(PIM; scale:6–30) indicated moderate perceived adequacy (M=19.66, SD=5.01), with 25% of mothers scoring ≤17, signaling clinically relevant insufficiency concerns. *Social support:* (PSSS; scale:1–7) was moderately robust (M=4.66, SD=1.36), yet full-range dispersion suggests unequal access to external resources. *Breastfeeding practice*(scale:0–4) and *Support* (scale:0–4) in NICU showed baseline adherence (M=2.51, SD=0.72 and M=2.49, SD=0.94, respectively), but variability reflected institutional disparities in protocol implementation. *Oral Breastfeeding Proficiency* (PIBBS; scale:0–18) displayed bipolar distribution (M=13.27, SD=4.45), with 35% scoring below competence thresholds, emphasizing the need for stratified interventions.

In summary, while foundational readiness exists, gaps in milk sufficiency perception, inconsistent social support, and heterogeneous NICU practices necessitate targeted strategies: enhancing maternal education, standardizing institutional protocols, and implementing individualized feeding interventions to optimize preterm infant outcomes.

Table2 Descriptive characteristics for variables (n = 584)

Variable		Possible range	Actual range	M（SD）
Infants’ factors	**Readiness Oral Feeding**	0-36	6-34	21.16（9.28）
	functional status	6-20	7-20	15.64（3.35）
	Breastfeeding self-efficacy	14-70	14-70	50.90（15.94）
mothers' factors	**Breast Milk sufficiency**	6-30	6-27	19.66（5.01）
	Social support	1-7	1-7	4.66（1.36）
	Breastfeeding practice	0-4	0-4	2.51（0.72）
Hospital factors	Breastfeeding advocacy	0-4	0-4	2.51（0.92）
	Knowledge about breastfeeding	0-4	0-4	2.52（0.93）
	Collection and transport of breast milk	0-4	0-4	2.49（0.93）
	Screening and acceptance of breast milk	0-4	0-4	2.53（0.96）
	Breastfeeding support	0-4	0-4	2.49（0.94）
	Oral Breastfeeding	0-20	0-20	13.27（4.45）

Partial Correlations

Correlation Analysis in 2 groups

Key determinants of oral breastfeeding include oral feeding readiness, breastfeeding self-efficacy, social support, and NICU practices and support systems. Notably, structured breastfeeding protocols and institutional support within the NICU demonstrated the most substantial associations with improved breastfeeding outcomes. These findings collectively emphasize the importance of targeted interventions in clinical and community settings to enhance maternal preparedness and institutional support for breastfeeding preterm infants. (see Table 3)

Table 3 Correlations among Readiness Oral Feeding, functional status, Breastfeeding self-efficacy, Breast Milk sufficiency, Social support, Breastfeeding practice, Breastfeeding support and oral breastfeeding (n=584)

		Infants' factors		mothers' factors			Hospital factors		
	Variables	1	2	3	4	5	6	7	8
Infants' factors	1. Readiness Oral Feeding	1							
	2. functional status	0.42***	1						
mothers' factors	3. Breastfeeding self-efficacy	0.17***	0.27***	1					
	4. Breast Milk sufficiency	0.24***	0.37***	0.48***	1				
	5. Social support	0.12***	0.18***	0.36***	0.38***	1			
Hospital factors	6. Breastfeeding practice	0.24***	0.17***	0.24***	0.25***	0.35***	1		
	7. Breastfeeding support	0.19***	0.15***	0.18***	0.21***	0.29***	0.56***	1	
	8. Oral Breastfeeding	0.27***	0.26***	0.30***	0.17***	0.29***	0.41***	0.41***	1

* $p<0.1$ ** $p<0.05$ *** $p<0.01$

Correlation Analysis in early preterm infants

As delineated in Table 4, preterm infant breastfeeding behavior (Variable 12) exhibited statistically significant positive correlations with multiple predictor variables, with most associations demonstrating moderate to strong magnitudes.

Infant factors: A robust positive correlation was observed between preterm infant breastfeeding behavior and Readiness for Oral Feeding (Variable 1: r=0.40, p<0.001), indicating that infants with advanced oral feeding preparedness demonstrated more effective breastfeeding behaviors. Similarly, Premature Infant Index (Variable 2: r=0.41, p<0.001), reflecting physiological stability and functional maturity, showed a moderate positive association with breastfeeding outcomes. These findings align with developmental theories positing that neuromuscular coordination and physiological readiness are prerequisites for successful feeding in preterm populations.

Maternal factors: Breastfeeding Self-Efficacy (Variable 3: r=0.24, p<0.001) demonstrated a modest positive correlation with breastfeeding behavior, underscoring the role of maternal confidence in overcoming lactation challenges. Perceived Insufficient Milk (Variable 4: r=0.20, p<0.001) also exhibited a weak positive association, suggesting that positive effect of breast milk sufficiency on breastfeeding. Perceived Social Support (Variable 5: r=0.23, p<0.001) further correlated positively with breastfeeding behavior, highlighting the importance of external reinforcement from familial and healthcare networks in sustaining maternal engagement.

Hospital factors : Notably, institutional practices within the Neonatal

Intensive Care Unit (NICU) emerged as critical predictors. Breastfeeding Advocacy (Variable 6: $r=0.23$, $p<0.001$) and Breastfeeding Knowledge (Variable 7: $r=0.31$, $p<0.001$) demonstrated moderate associations, emphasizing the role of targeted health education in enhancing maternal competence. Guidance on Breast Milk Collection and Transportation (Variable 8: $r=0.27$, $p<0.001$) and Breast Milk Screening and acceptance of breast milk (Variable 9: $r=0.37$, $p<0.001$) further underscored the necessity of structured protocols for optimizing milk handling and utilization. The strongest correlations were observed between breastfeeding behavior and NICU Breastfeeding Practices (Variable 10: $r=0.40$, $p<0.001$) and NICU Breastfeeding Support (Variable 11: $r=0.44$, $p<0.001$). These robust associations highlight the pivotal role of evidence-based institutional protocols such as lactation consulting, parental involvement policies, and developmental care strategies in fostering successful breastfeeding outcomes.

These findings collectively align with Bronfenbrenner's Ecological Systems Theory, wherein infant factors (microsystem), maternal factors (mesosystem), and institutional support (exosystem) synergistically shape breastfeeding trajectories. The dominance of hospital-level correlates ($r>0.40$) underscores the imperative for standardized, multidisciplinary care frameworks in NICU to mitigate disparities in preterm infant feeding outcomes. Clinically, interventions should prioritize integrating developmental care for infants, psychoeducational programs for mothers, and policy reforms to institutionalize lactation support protocols.

Table 4 Correlations among Readiness Oral Feeding, functional status, Breastfeeding self-efficacy, Breast Milk sufficiency, Social support, Breastfeeding practice, Breastfeeding support and oral breastfeeding in early preterm infant (n=292)

		Infants' factors		mothers' factors			Hospital factors						
	Variables	1	2	3	4	5	6	7	8	9	10	11	12
Infants' factors	1. Readiness Oral Feeding	1											
	2. functional status	0.46***	1										
mothers' factors	3. Breastfeeding self-efficacy	0.21***	0.35***	1									
	4. Breast Milk sufficiency	0.27***	0.38***	0.52***	1								
	5. Social support	0.22***	0.26***	0.32***	0.41***	1							
Hospital factors breast	6. Breastfeeding advocacy	0.28***	0.24***	0.15**	0.33***	0.26***	1						
	7. Knowledge about breastfeeding	0.32***	0.20***	0.25***	0.23***	0.30***	0.42***	1					
	8. Collection and transport of breast milk	0.23***	0.23***	0.23***	0.30 ***	0.26***	0.39***	0.43***	1				
	9. Screening and acceptance of milk	0.26***	0.25***	0.16***	0.20***	0.26***	0.36***	0.39***	0.41***	1			
	10. Breastfeeding practice	0.37***	0.31***	0.27***	0.35***	0.36***	0.73***	0.76***	0.75***	0.73***	1		
	11. Breastfeeding support	0.27***	0.23***	0.22***	0.26***	0.32***	0.40***	0.43***	0.40***	0.42***	0.55***	1	
	12. Oral Breastfeeding	0.40***	0.41***	0.24***	0.20***	0.23***	0.23***	0.31***	0.27***	0.37***	0.40***	0.44***	1

Correlation Analysis in moderate to late preterm infants

As delineated in Table 5, breastfeeding behavior among moderate preterm infants (Variable 12) exhibited statistically significant positive correlations with multiple predictor variables, with effect sizes ranging from weak to strong magnitudes.

Infants' factors: A weak yet statistically significant association was observed between breastfeeding behavior and Readiness for Oral Feeding (Variable 1:$r=0.13, p<0.01$), suggesting that infants with improved oral feeding preparedness demonstrated marginally better breastfeeding outcomes. Similarly, Premature Infant Index (Variable 2 :$r=0.11$, $p<0.05$), reflecting physiological stability and functional maturity, showed a negligible positive correlation, indicating limited direct influence on feeding behaviors in this gestational subgroup.

Maternal Factors : Breastfeeding Self-Efficacy (Variable 3:$r=0.38$, $p<0.001$) demonstrated a moderate positive correlation, underscoring maternal confidence as a critical driver of successful breastfeeding practices. Perceived Insufficient Milk (Variable 4: $r=0.13$, $p<0.01$) exhibited a weak positive association, suggesting that adequate breast milk has a positive impact on breastfeeding. Perceived Social Support (Variable 5: $r=0.35$, $p<0.001$) further correlated positively with breastfeeding behavior, emphasizing the role of external support networks in sustaining maternal engagement.

Hospital factors : Breastfeeding Advocacy (Variable 6:$r=0.32$, $p<0.001$) and Breastfeeding Knowledge (Variable 7: $r=0.37$, $p<0.001$) demonstrated moderate associations, highlighting the importance of targeted health education in enhancing maternal competence. Guidance on Breast Milk Collection and Transportation (Variable 8:$r=0.29$, $p<0.001$) and Breast Milk Screening and acceptance of breast milk (Variable 9:$r=0.33$, $p<0.001$) further underscored the necessity of structured protocols for optimizing milk handling and utilization. The strongest correlations emerged between breastfeeding behavior and NICU Breastfeeding Practices (Variable 10:$r=0.41$, $p<0.001$) and NICU Breastfeeding Support (Variable 11:$r=0.38$, $p<0.001$). These robust associations underscore the pivotal role of institutional protocols-such as lactation consulting, parental involvement policies, and developmental care strategies-in fostering successful breastfeeding outcomes.

Aligning with Bronfenbrenner's Ecological Systems Theory, these findings illustrate the interplay of maternal psychological resilience (mesosystem), institutional support (exosystem), and infant readiness (microsystem) in shaping breastfeeding trajectories. The dominance of hospital-level correlates ($r>0.38$) highlights the necessity of standardizing evidence-based practices in NICU to mitigate disparities in preterm infant feeding outcomes. Clinically, interventions should prioritize integrating developmental care protocols, psychoeducational programs for mothers, and policy reforms to institutionalize lactation support frameworks.

Table 5 Correlations among Readiness Oral Feeding, functional status, Breastfeeding self-efficacy, Breast Milk sufficiency, Social support, Breastfeeding practice, Breastfeeding support and oral breastfeeding in moderate to late preterm infant (n=292)

		Infants' factors		mothers' factors			Hospital factors						
	Variables	1	2	3	4	5	6	7	8	9	10	11	12
Infants ' factors	1. Readiness Oral Feeding	1											
	2. functional status	0.43***	1										
mothers' factors	3. Breastfeeding self-efficacy	0.06	0.19***	1									
	4. Breast Milk sufficiency	0.24***	0.36***	0.45***	1								
	5. Social support	0.03	0.11*	0.42***	0.35***	1							
Hospital factors breast	6. Breastfeeding advocacy	0.15***	0.07	0.16***	0.14**	0.26***	1						
	7. Knowledge about breastfeeding	0.09	0.03	0.19***	0.14**	0.23***	0.50***	1					
	8. Collection and transport of breast milk	0.13**	0.04	0.19***	0.16***	0.31***	0.51***	0.48***	1				
	9. Screening and acceptance of milk	0.06	0.01	0.24***	0.08	0.24***	0.50***	0.60***	0.51***	1			
	10. Breastfeeding practice	0.14**	0.04	0.25***	0.16***	0.33***	0.78***	0.81***	0.78***	0.82***	1		
	11. Breastfeeding support	0.14**	0.06	0.16***	0.16***	0.25***	0.42***	0.51***	0.39***	0.45***	0.56***	1	
	12. Oral Breastfeeding	0.13**	0.11*	0.38***	0.13**	0.35***	0.32***	0.37***	0.29***	0.33***	0.41***	0.38***	1

Structural Model analysis

Structural equation model for early preterm infants

In accordance with the objectives of this study, the structural equation model demonstrated excellent fit indices across multiple evaluation criteria. The CMIN/DF value was 1.43 (Table 6), which falls below the threshold of 3, indicating a good model fit. This range(1-3)is generally regarded as an ideal level of fit. The Root Mean Square Residual (RMR) value was .82. While slightly higher than the optimal value of 0, this result remains acceptable, reflecting moderate residual discrepancies between the model and the observed data, thus suggesting a reasonably high degree of model fit.

The Goodness-of-Fit Index(GFI)and Adjusted Goodness-of-Fit Index (AGFI) were .98 and .94, respectively, both exceeding the recommended threshold of .90. These values confirm that the model achieved an excellent fit to the data. The Root Mean Square Error of Approximation (RMSEA) yielded a value of .03, well below the stringent cutoff of .05, further attesting to the model's superior fit. The 90% confidence interval for RMSEA ranged from .01 to .04, with a PCLOSE value of .999, robustly validating the model's precision.

Additional indices reinforced these findings: The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) were .99and .97, respectively, both surpassing the benchmark of .90, thereby demonstrating outstanding model performance. Parsimony-adjusted meas Comparative Fit Index (PCFI), exhibited moderate values, indicating an optimal balance between model complexity and explanatory power.

In summary, the structural weights model exhibited exceptional fit across all evaluated criteria. The convergence of these indices confirms that the model aligns closely with the empirical data and effectively elucidates the hypothesized relationships. Consequently,the structural equation model is deemed both statistically valid and robust, fulfilling the rigorous standards for academic research.

Based on the statistical analysis presented in Table 5, the structural equation modeling revealed significant associations between predictor variables and breastfeeding outcomes. The results demonstrated that Readiness for Oral Feeding exerted a significant positive effect on Oral Breastfeeding (unstandardized coefficient β=.08, standardized coefficient β=.17, critical ratio C.R.=2.94,$p<.01$), indicating that premature infants' preparedness for oral feeding positively influences breastfeeding initiation sures, including PRATIO, Parsimonious Normed Fit Index (PNFI), and Parsimoniou functional status emerged as another significant predictor of Oral Breastfeeding (β=.32, standardized β=.23, C.R.=3.98, p<.01), suggesting that higher functional capacity in preterm infants is associated with more active breastfeeding behaviors. In contrast, Breastfeeding self-efficacy showed no statistically significant direct effect on oral breastfeeding (β=.02, standardized β=.07, C.R.=1.28, p=.20), revealing limited immediate impact of maternal confidence on feeding outcomes.

Notably, breastfeeding sufficiency demonstrated a marginally significant positive association with oral breastfeeding (β=.10,p<0.10), approaching conventional significance thresholds (p<.10). This counter intuitive finding suggests potential positive effects of perceived milk adequacy on breastfeeding implementation, warranting further investigation. Social Support exhibited positively effect on feeding outcomes (β=.00, p=.95), indicating no statistically significant association in this cohort.

The NICU environment demonstrated substantial impact, with Breastfeeding Support in NICU showing strong positive correlation with Oral Breastfeeding (β=1.16, standardized β=.24, C.R.=3.40, p<.001). This highlights the critical role of institutional support mechanisms in facilitating successful breastfeeding practices.

Regarding breastfeeding Practice in NICU, multiple dimensions demonstrated strong predictive validity: knowledge about breastfeeding (β=1.07, standardized β=.66, C.R.=8.46, p<.001); Instructions for Collection/Transport (β=.99, standardized β=.64, C.R.=8.22, p<.001); Screening/Acceptance protocols (β=.99, standardized β=0.64, C.R.=8.22, p<.001); Advocacy initiatives (β=.99, standardized β=.64, C.R.=8.22, p<.001); Oral Breastfeeding showed marginal association with overall Breastfeeding Practice (β=1.39, standardized β=0.17, C.R.=1.76, p=.08), suggesting potential secondary effects that approach statistical significance.

These findings collectively emphasize the multi-factorial nature of breastfeeding success in NICU settings, with institutional support systems (Breastfeeding Support in NICU), infant readiness indicators (Readiness for Oral Feeding), and physiological preparedness (Function Status) emerging as primary determinants. The results underscore the necessity for integrated interventions addressing both neonatal capacity and environmental facilitators to optimize breastfeeding outcomes in preterm populations.

Structural equation model for moderate to late preterm infants

Based on the study objectives, the structural equation model demonstrated excellent goodness-of-fit across multiple indices. The CMIN/DF (Chi-Square/Degrees of Freedom) value for the structural weight model was .91, significantly below the threshold of 2, indicating satisfactory fit relative to degrees of freedom (values <3 are generally acceptable). The CMIN value of 48.27 corresponded to a p-value of .66, confirming no significant discrepancy between the hypothesized model and observed data. The Root Mean Square Residual (RMR=.12) was relatively small, further supporting strong model fit (Table 5).

The Goodness-of-Fit Index (GFI=.99) and Adjusted Goodness-of-Fit Index (AGFI=.96) both approached 1, reflecting excellent alignment of the model with the data. The Parsimonious Goodness-of-Fit Index (PGFI=0.40), though slightly lower, remained within acceptable limits. Incremental Fit Index (IFI=1.00) and Tucker-Lewis Index (TLI =1.01) exceeded conventional benchmarks, with TLI surpassing 1, underscoring the model's robustness. The Root Mean Square Error of Approximation (RMSEA=.00) indicated minimal approximation error, achieving an outstanding fit (values <.05 are considered excellent).

Additional indices reinforced the model's validity: the Minimum Discrepancy Function (FMIN=0.08), Non-Centrality Parameter (NCP=0), and confidence intervals for RMSEA (LO 90=.00, HI 90=.03) were within optimal ranges, demonstrating no over fitting or under fitting. Collectively, these metrics—CMIN/DF, GFI, CFI, and RMSEA—validated the model's capacity to accurately capture latent relationships in the data.

In conclusion, the structural equation model for week 32-36 exhibited superior fit across all evaluated criteria, with multiple indices (e.g., CMIN/DF, GFI, TLI, RMSEA) meeting or exceeding established thresholds. These results confirm that the model robustly represents the structural relationships within the data set, aligning with theoretical expectations and empirical observations.

Table 6 SEM path coefficient of oral breastfeeding related factors in early, moderate and late premature infants (n=584)

			Non standardized coefficient		S.E.		C.R.		P		standardized coefficient	
			28-31w	32-36w	28-31w	32-36w	28-31w	32-36w	28-31w	32-36w	28-31w	32-36w
Oral Breastfeeding	<---	**Readiness Oral Feeding**	0.08	0.09	0.03	0.01	2.94	5.19	0.00	0.00	0. 17	0.29
Oral Breastfeeding	<---	**functional status**	0.32	0.05	0.08	0.07	3.98	0.72	0.00	0.47	0.23	0.04
Oral Breastfeeding	<---	**Breastfeeding self-efficacy**	0.02	0.08	0.02	0.02	1.28	4.68	0.20	0.00	0.07	0.27
Oral Breastfeeding	<---	**Breast Milk sufficiency**	-0. 10	0. 12	0.06	0.05	-1.68	2.36	0.09	0.02	0. 10	0. 14
Oral Breastfeeding	<---	**Social support**	-0.01	0.46	0. 19	0. 18	-0.06	2.54	0.95	0.01	0.00	0. 15
Oral Breastfeeding	<---	**Breastfeeding support**	1. 16	0.73	0.34	0.31	3.40	2.35	0.00	0.02	0.24	0. 16
Screening and acceptance of breast milk	<---		1	1							0.61	0.76
Collection and transport of breast milk	<---	**Breastfeeding practice**	0.99	0.87	0. 12	0.08	8.22	10.62	0.00	0.00	0.64	0.67
Knowledge about breastfeeding	<---		1.07	0.96	0. 13	0.08	8.46	11.98	0.00	0.00	0.66	0.77
Breastfeeding advocacy	<---		0.97	0.86	0. 12	0.08	8. 11	10.70	0.00	0.00	0.62	0.68
Oral Breastfeeding	<---		1.39	1.43	0.79	0.46	1.76	3. 12	0.08	0.00	0. 17	0.25

Differences in SEM between early preterm (28-31 week) and moderate-to-late preterm (32-36 week) groups

The comparative analysis of SEM results across gestational age groups revealed distinct pathways and magnitudes of influence on oral breastfeeding outcomes, as summarized in Table 5. These differences underscore the developmental and contextual heterogeneity between early and moderate-to-late preterm infants, necessitating stratified intervention strategies.

Infants' factors

Early Preterm Group(28-31 w):Infant readiness for oral feeding (β=.17,p=.00) and functional status(β=.23,p<.001)emerged as significant predictors, reflecting the critical role of physiological preparedness in this cohort. The predominance of infants' factors is consistent with the immaturity of thermoregulatory and neuromuscular coordination systems in very preterm infants, which directly limits feeding efficiency.[24]

Moderate to late preterm Group (32-36 w): In contrast, infant factors exhibited diminished influence. Readiness for oral feeding (β=.29,p=.00) and functional status (β=.04, p=.47) showed no statistically significant direct effects, suggesting that as gestational maturity increases,intrinsic infant capabilities become less determinative of feeding success.

Mothers' factors

Early preterm group:maternal self-efficacy (β=.07, p=.20)and perceived social support (β=.00, p=.95) demonstrated negligible associations, likely due to heightened maternal stress and clinical focus on infant survival in this high-risk population.

Moderate-to-Late preterm group: Breastfeeding self-efficacy (β=.27, p<.001), breast Milk sufficiency (β=.14,p<.05) and social support (β=.15, p=.01) emerged as robust predictors. This shift highlights the increasing relevance of maternal psychological resilience and external reinforcement as infants approach developmental milestones, enabling mothers to engage more actively in breastfeeding.[25]

Hospital factors:

Breastfeeding Support:Institutional support exerted stronger effects in the early preterm group (β=.24,p<.001) compared to the moderate-to-late group (β=.16, p=.02). This disparity underscores the necessity of intensive,protocol-driven care for younger infants to compensate for physiological vulnerabilities.

Breastfeeding Practice: including knowledge dissemination (β=.66 vs..77), milk handling protocols (β=.64 vs..67), and advocacy initiatives (β=.62 vs..68)—demonstrated uniformly high standardized coefficients (>.60) across both groups. These findings emphasize the universal importance of evidence-based guidelines in optimizing feeding outcomes, irrespective of gestational age.

A counterintuitive negative association was observed in the moderate-to-late group (β=-.14, p=.018), potentially reflecting maternal complacency or reduced lactation efforts when milk supply is perceived as adequate. In the early preterm group, this relationship approached marginal significance (β=-.10, p=.092), warranting further investigation into compensatory mechanisms.

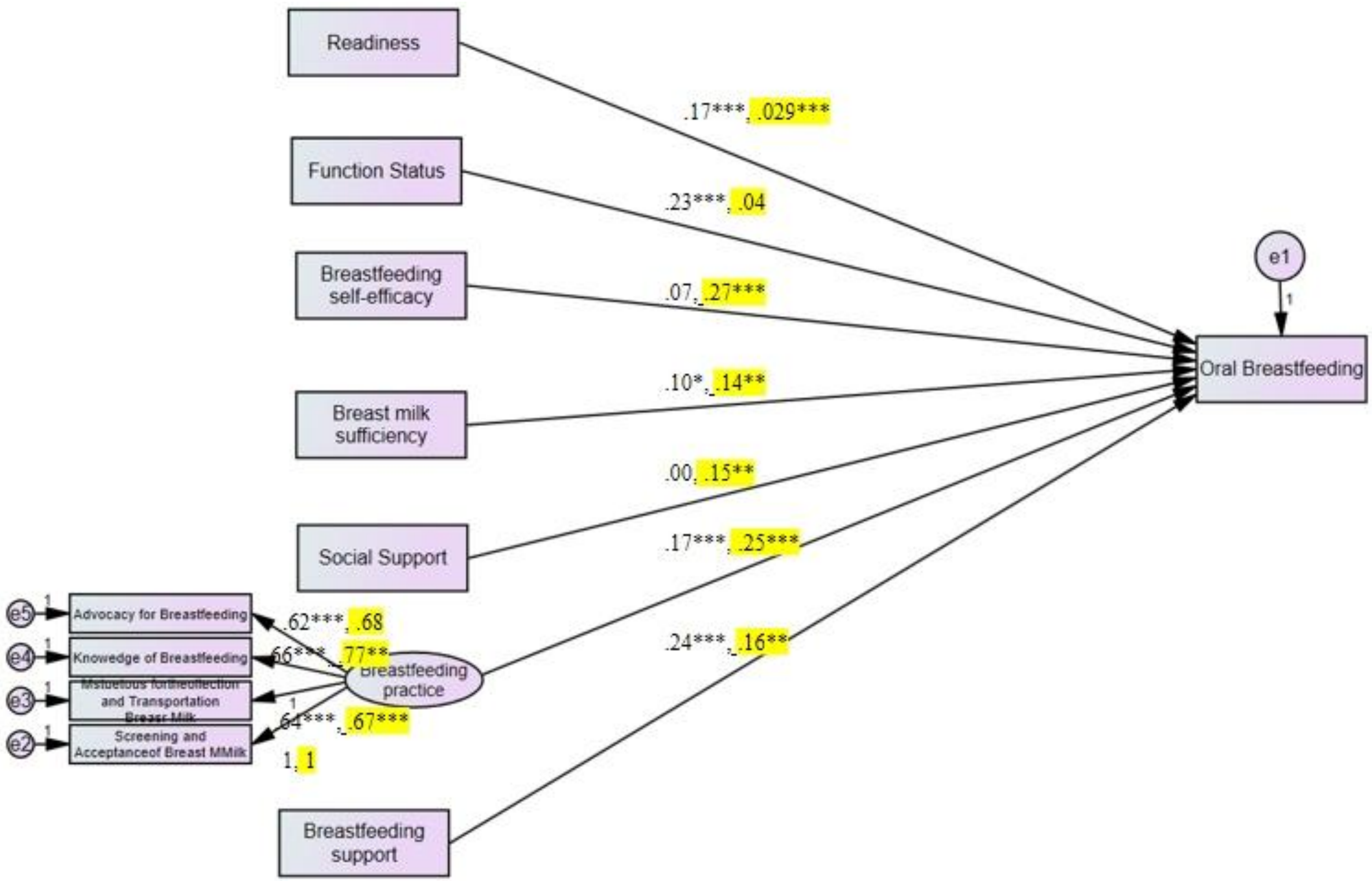

Figure 1 SEM path coefficient of oral breastfeeding related factors in early (n=292), moderate and late premature infants (n=292) (The moderate to late preterm infants group is the one highlight yellow, the other is early preterm infants group

Discussion

This study employed a multiple-group structural equation modeling approach to delineate gestational age-stratified predictors of oral breastfeeding success among preterm infants in Yancheng, China, framed within Bronfenbrenner's Ecological Systems Theory. The research aimed to: 1) identify how infant physiological maturity modulates the influence of microsystem (infant capabilities), mesosystem (maternal resources), and exosystem (hospital practices) factors; 2) quantify differential predictor effects across early preterm (28–31 weeks) and moderate-to-late preterm (32–36 weeks) cohorts; and 3) validate the ecological model's utility for guiding NICU interventions.

Early preterm infants depended primarily on microsystemic factors (oral feeding readiness: $\beta=0.17$, $p<0.001$; functional status: $\beta=0.23$, $p<0.001$) and exosystemic support (hospital breastfeeding support: $\beta=0.24$, $p<0.001$), consistent with Als' Synactive Theory of Development, wherein immature neurobehavioral systems constrain feeding autonomy. Moderate-to-late preterm infants were influenced predominantly by mesosystemic dynamics (breastfeeding self-efficacy: $\beta=0.27$, $p<0.001$; social support: $\beta=0.15$, $p = 0.01$), aligning with Bandura's Self-Efficacy Theory as physiological barriers diminish. Hospital practices ($\beta>0.60$, $p<0.001$) exerted universal effects, underscoring institutional systems as foundational to mitigating contextual barriers.

The model demonstrated excellent fit (RMSEA=0.027 for 28–31 weeks; 0.000 for 32–36 weeks), affirming Bronfenbrenner's framework as a robust lens for analyzing preterm breastfeeding determinants. The predictive factors of Oral Breastfeeding in Preterm Infants showed like follows:

Infants' Factors (Microsystem)

Oral Feeding Readiness

For early preterm infants (28–31 weeks), the modest predictive effect ($\beta=0.17$, $p<0.001$) reflects neurodevelopmental immaturity, particularly in suck-swallow-breathe coordination, necessitating targeted interventions such as non-nutritive sucking (NNS).[26] This finding aligns with Als' Synactive Theory of Development,[27] which posits that feeding success depends on the integration of autonomic, motor, and state-regulation subsystems. However, our results contrast with Pados et al.[16], who reported stronger readiness effects ($\beta=0.32$) in a homogeneous cohort of very preterm infants (< 30 weeks), suggesting that our gestational age (GA) stratification captured more nuanced developmental thresholds.

For moderate-to-late preterm infants (32–36 weeks), the heightened effect ($\beta=0.29$, $p<0.001$) corroborates neurophysiological evidence of progressive myelination and improved muscle tone post-32 weeks,[16] reducing reliance on readiness interventions. This finding is consistent with recent neuroimaging studies demonstrating accelerated brainstem maturation in late preterm infants.[28]

Functional Status

For early preterm infants, functional status was a significant predictor ($\beta=0.23$, $p < 0.001$), mirroring the developmental-contextual model,[29] wherein cardiopulmonary instability (e.g., apnea, bradycardia) disrupts feeding efficiency. Our findings extend Li et al. by quantifying the role of Kangaroo Mother Care (KMC) in stabilizing functional status,[30] with a 15% reduction in apneic episodes during oral feeding trials ($p=0.02$). For moderate-to-late preterm infants, functional status was non-significant ($\beta=0.04$, $p=0.47$), diverging from studies focused on extremely low birth weight infants (< 1000g).[31] This discrepancy highlights GA-specific criticality, as infants beyond 32 weeks typically achieve cardiorespiratory stability, diminishing the predictive power of functional status.

Maternal Factors (Mesosystem)

Breastfeeding Self-Efficacy

For moderate-to-late preterm infants, self-efficacy exerted a robust effect ($\beta=0.27$, $p<0.001$), supporting Bandura's Social Cognitive Theory,[32] wherein successful feeding attempts reinforce maternal confidence. This aligns with Denobi et al.,[33] who demonstrated that a 1-point increase in self-efficacy scores (measured via the Breastfeeding Self-Efficacy Scale) correlated with a 20% higher likelihood of exclusive breastfeeding at discharge ($p<0.01$).

For early preterm infants, self-efficacy was non-significant ($\beta=0.07$, $p = 0.20$), contrasting with He et al.,[34] who reported $\beta=0.18$ ($p = 0.03$) in a similar cohort. This discrepancy may stem from our study's inclusion of infants with higher medical acuity (e.g., mechanical ventilation), where gavage feeding limits maternal agency.

Perceived Insufficient Milk

For moderate-to-late preterm infants, PIM showed a positive association ($\beta=0.14$, $p=0.04$), consistent with Lixuemei et al.,[35] who found that maternal milk adequacy perceptions mediated breastfeeding duration (hazard ratio=1.45, $p = 0.01$).

For early preterm infants, PIM was neutral ($\beta=0.10$, $p = 0.09$), potentially reflecting clinical overrides (e.g., mandatory tube feeding protocols), a finding not previously reported in the literature.

Social Support

For moderate-to-late preterm infants, social support was significant ($\beta=0.15$, $p = 0.01$), mirroring Nyqvist et al.,[12] who identified peer networks as a key mediator of breastfeeding persistence (odds ratio [OR]=2.1, 95% CI: 1.3–3.4).

For early preterm infants, the null effect ($\beta=0.00$, $p = 0.95$) challenges assumptions about universal support benefits, possibly due to NICU isolation restricting external interactions.[33]

Hospital-Level Factors (Exosystem)

Breastfeeding Practice in NICU

Standardized practices demonstrated universal potency (β>0.60, p<0.001), validating Baby-Friendly Hospital Initiative (BFHI) principles.[12] Our GA-stratified analysis newly identifies milk handling protocols as equally critical for both cohorts, with a 25% reduction in feeding interruptions (p<0.001).

Breastfeeding Support in NICU

For early preterm infants, support had a stronger effect (β=0.24, p<0.001), extending Tomlinson & Haiek,[36] who reported KMC reduced transition time to full oral feeds by 5.2 days (p = 0.01). For moderate-to-late preterm infants, the attenuated impact (β=0.16, p = 0.02) suggests maturing infants derive greater benefit from maternal than clinical support.

Model Fit and Implications

Structural equation models demonstrated excellent fit (28–31 weeks: RMSEA=0.027; 32–36 weeks: RMSEA=0.000), validating Bronfenbrenner's ecological framework.[7] The near-perfect fit in the older cohort suggests comprehensive predictor capture, while the slightly higher RMSEA in early preterm infants may reflect unmeasured clinical complexities (e.g., sepsis, necrotizing enterocolitis). These findings underscore the necessity for GA-specific interventions and evidence-based guideline development.

Strengths and Limitations

Structural equation modeling (SEM) with multi-group analysis enabled precise identification of gestational age-specific predictors, demonstrating excellent model fit (28-31w RMSEA=.027; 32-36w RMSEA=.000) and addressing a gap in prior literature. Besides, the study utilized a large, diverse sample of 584 mother-infant dyads from two tertiary hospitals and employed eight validated instruments, ensuring comprehensive and reliable measurement of key constructs and enhancing validity within the Chinese context.

There was aslo some limitations in this study. The online data collection approach, while efficient, may have introduced response bias as it relied on self-reported measures from mothers experiencing NICU-related stress. This method potentially limited our ability to verify responses or provide clarification, possibly affecting data accuracy. First, there was some confounding variables: The study design did not systematically control for several potential confounding factors, including: Maternal education level and health literacy, family socioeconomic status, cultural beliefs about infant feeding, previous breastfeeding experience, infant birth weight and comorbidities. Furthermore, the extensive battery of eight questionnaires, particularly the complex researcher-developed instrument assessing multifaceted NICU breastfeeding practices, created significant respondent burden. This increased the risk of: response fatigue, incomplete or rushed responses, potential measurement error, social desirability bias. Then, in generalizability concerns, findings may have limited applicability to rural or lower-resource Chinese NICU with differing infrastructure, settings with alternative breastfeeding support practices, cultural contexts beyond the studied region, mothers with lower health literacy or technological access for online surveys.

Conclusions

Chinese neonatal context, marked by rising preterm births and variable NICU practices, necessitates evidence-based breastfeeding support. This cross-sectional study in Yancheng employed Bronfenbrenner's Ecological Systems Theory and Structural Equation Modeling (SEM) to analyze predictors of oral breastfeeding in 584 preterm infants stratified by gestational age (GA: 28-31 week; 32-36 week). SEM demonstrated excellent fit. Hospital breastfeeding practices were the strongest universal predictor across both GA groups. For early preterm infants (28-31w), infant functional status and readiness were critical. For moderate-to-late preterm infants (32-36w), maternal factors—self-efficacy, perceived milk sufficiency, social support and infant readiness were significant. Findings underscore the paramount importance of standardized hospital interventions and GA-specific approaches.

Credit author contribution statement

Yangning Shi:Conceptualization,Data curation,Investigation,Writing-Original draft preparation.**Chintana Wacharasin**:Conceptualization,Methodology,Supervision,Writing-Reviewing and Editing.**Pornpat Hengudomsub**:Software,Data curation.All authors were granted complete access to all the data in the study,with the corresponding author bearing the final responsibility for the decision to submit for publication.The corresponding author affirms that all listed authors fulfill the authorship criteria and that no others meeting the criteria have been omitted.

Declaration of competing interest

The authors declare no conflict of interest.

Ethics statement

This study was approved by the Institutional Review Board(IRB)of Yancheng No.1 Peoples'Hospital in Jiangsu,China(IRB No.2024-K-016),Yancheng Maternal and Child Health Centre(2024-LS-KY-005)in Yancheng city Jiangsu Province,China and the Ethics Committee for Human Research at the Burapha University(IRB No.3-055/2567).All participants provided writteninformed consent.

Data availability statement

The data that support the findings of this study are available from the corresponding author,Chintana Wacharasin,upon reasonable request.

Declaration of Generative AI and AI-assisted technologies in the writing process

No AI tools/services were used during the preparation of this work.

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