

First-week feeding category and time to first recorded formula-only milk feeding through six months postpartum: a discrete-time survival analysis of a hospital follow-up cohort

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Abstract

Background

Routine clinical data rarely capture when women who begin breastfeeding first record formula as the sole milk source, or which early characteristics mark women at higher risk. We described its timing and examined first-week feeding category as an early marker.

Methods

We analyzed a nurse-led postpartum follow-up program at a tertiary hospital in Taiwan (2021–2024) with assessments at one week and one, two, four, and six months. Among 651 women (one eligible pregnancy per woman) providing any breast milk at one week, the outcome was the first assessment at which formula was the sole milk source, irrespective of complementary foods. Discrete-time survival models estimated conditional odds ratios (OR) for first-week feeding category (direct breastfeeding, expressed breast milk, or mixed feeding), obstetric factors, Edinburgh Postnatal Depression Scale (EPDS) scores, and mastitis.

Results

During follow-up, 318 first formula-only records occurred across 1,511 evaluable person-periods; life-table cumulative incidence was 64.7% (57.2% when censoring at the first missed visit; 161 of 651 women censored earlier), and the six-month probability of remaining free of a first formula-only record was 35.3% (95% CI 31.1–39.5). First formula-only records were concentrated in the first four postpartum months, with the monthly-equivalent point estimate numerically highest at one to two months (20.1%). Compared with mixed feeding, pooled adjusted odds were lower for direct breastfeeding (OR 0.14, 95% CI 0.08–0.26) and expressed breast milk (0.34, 0.20–0.59). There was evidence of heterogeneity in associations across follow-up intervals (penalized-likelihood interaction $p = 0.035$), so pooled estimates are common-effect summaries. Cesarean delivery was associated with higher odds (OR 1.49, 1.12–1.97).

Conclusions

Under the available-visit analysis, first formula-only records were concentrated in the first four postpartum months, with the monthly-equivalent point estimate numerically highest from one to two months. First-week feeding category was strongly associated with a first formula-only record, but the observational design and category composition preclude causal interpretation of feeding route. Feeding status recorded at the first-week visit may provide a simple clinical marker for considering preference-sensitive support from before one month through four months.

Background

Exclusive breastfeeding for six months remains the internationally recommended standard [1, 2]; the outcome studied here, the first recorded transition to formula as the sole milk source, is distinct from exclusive-breastfeeding duration, yet in high-income settings, including Taiwan, a large share of women who begin breastfeeding record formula as the sole milk source well before that point [3, 4].

Understanding when this transition occurs, and which characteristics visible in the first days after birth mark women at higher risk, matters for the timing and targeting of lactation support. Much of the existing evidence comes from dedicated infant-feeding surveys; comparatively few studies describe the transition using feeding status recorded repeatedly within routine postpartum care.

Two candidate early markers are of particular interest. First, the first-week feeding category, direct feeding at the breast, feeding expressed breast milk, or already combining breast milk with formula, is plausibly linked to the establishment of milk supply and of the feeding relationship, and qualitative work indicates that women feeding expressed milk face distinct sustainability challenges compared with those feeding directly at the breast [5]. Second, maternal depressive symptoms and breastfeeding cessation have been linked in some cohorts [6], and in Taiwanese women early breastfeeding has been associated with a lower risk of postpartum depression, indicating that the feeding-mood relationship may run in both directions [7]; cesarean delivery has been associated with lower breastfeeding initiation and continuation [8]. In Taiwan, where most women in this cohort spent the early weeks in postpartum care centers practicing traditional doing-the-month confinement [9, 10], the relationship between institutional confinement care and feeding trajectories is also of local policy interest. Care-center residence was common (about 82%) in this cohort, which limits its discriminatory value as a proxy for socioeconomic position.

Using a hospital follow-up cohort in which feeding status was recorded at approximately one week, one month, two months, four months, and six months after delivery, we aimed to (1) describe the timing of the first formula-only milk-feeding record among women providing any breast milk at one week, and (2) estimate the associations of first-week feeding category, obstetric factors, Edinburgh Postnatal Depression Scale (EPDS) scores, and mastitis with that first record in a discrete-time survival framework. Unlike studies that classify feeding only as exclusive versus non-exclusive breastfeeding, this cohort distinguished direct breastfeeding, expressed breast-milk feeding, and mixed feeding at one week, allowing assessment of whether feeding route carries prognostic information beyond early formula exposure.

Methods

Study design and setting

We conducted a retrospective cohort study, reported according to the STROBE statement [11], at a medical center adjacent to the capital city in northern Taiwan. Since 2021 the center has operated a structured program of scheduled postpartum follow-up visits at approximately one week, one month,

two months, four months, and six months after delivery. The earlier visits serve obstetric indications (assessment of the delivery wound at one week, wound healing at one month, and resolution of lochia with the opportunity for cervical cytology at two months), and at each visit trained nurses record wound status, lochia, infant feeding, and infant weight, and the women self-complete the Chinese version of the EPDS as a paper questionnaire at the first three visits [12]. The infant-feeding items analyzed here were collected in the program between November 2021 and September 2024; deliveries outside this window have no feeding records and were not eligible, which reflects the period of data collection rather than loss to follow-up.

Participants

Women were eligible if they had a feeding record at the one-week visit, could be linked to the delivery database (6,471 deliveries, 2017 to 2025), and were providing any breast milk at one week (direct breastfeeding, expressed breast milk, or mixed breast milk and formula). The 54 women for whom formula was the sole milk source at one week were excluded from the analysis cohort; they may have provided breast milk before that assessment. Where a woman contributed more than one pregnancy, only the first was retained. No twin pregnancies were recorded in the analysis cohort.

Outcome and follow-up

The outcome was the first assessment at which no breast milk was recorded and formula was the sole milk source, irrespective of complementary-food intake, evaluated at the one-month, two-month, four-month, and six-month visits (median 36, 66, 126, and 187 days after delivery); at the four- and six-month visits, categories recorded with complementary foods were classified by their milk-feeding component. This represented a first recorded status rather than confirmed permanent cessation. Women without an observed event were censored at their last breast-milk assessment; a missed visit did not permanently censor eligibility, and women could contribute again at a later observed assessment. The event was assigned to the first assessment at which formula was the sole milk source. This first-transition definition was retained even if breast-milk feeding was later recorded again, which occurred in nine women. A program-generated indicator of transition to formula as the sole milk source, coded only for women previously recorded as providing breast milk, corroborated the outcome definition.

Exposures and covariates

The exposure of interest was the first-week feeding category: direct breastfeeding, expressed breast milk, or mixed breast milk and formula. Nurses record a single feeding category per visit: direct breastfeeding denotes any feeding at the breast without formula, and women combining at-breast feeding with expressed breast milk were classified as direct breastfeeding; expressed breast milk denotes breast milk fed exclusively by bottle, and mixed feeding denotes breast milk with any formula. The primary contrast was breast-milk-only feeding (direct or expressed) versus mixed feeding, which indexes whether formula was already in use; a three-category model (reference, mixed feeding) and a within-breast-milk-only contrast of direct versus expressed feeding were fitted to separate feeding route

from formula exposure. Covariates from the delivery record were cesarean delivery, primiparity, maternal age (per 10 years), gestational age, and birth weight; the institutional high-risk designation is a delivery-record flag assigned by the treating obstetrician for obstetric or medical risk factors and is reported descriptively. Postpartum care-center residence at one week was recorded at the first visit. EPDS scores were examined both as the baseline first-week score (threshold 10) and as a time-varying covariate equal to the most recent available score before each interval (the two-month score serving both the two-to-four- and four-to-six-month intervals). Mastitis defined a lagged time-varying indicator equal to any report at assessments before the start of each interval, keeping exposure ascertainment prior to the interval-ending outcome.

Statistical analysis

The cumulative probability of remaining free of a first formula-only record was estimated with a discrete-time life table, with Wilson confidence intervals for interval hazards and Greenwood-based log-minus-log confidence intervals for the survival function. Because the four risk intervals differ in width (one, one, two, and two months), interval hazards are probabilities per interval; monthly-standardized hazards were derived as $1-(1-h)^{(1/k)}$, where k is the interval width in months, assuming a constant monthly conditional hazard within each multi-month interval. Associations were estimated with discrete-time survival models: person-period logistic regression with indicator variables for the four risk intervals [13], yielding conditional odds ratios (OR) for the event within an interval, with Wald 95% confidence intervals; in the primary models the covariate effects were constrained to be common across intervals; because per-interval event probabilities reached 31.6%, these ORs exceed the corresponding risk ratios in magnitude and are not interpreted as hazard or risk ratios. Person-periods were constructed only for intervals ending in an observed assessment: a missed assessment generated no person-period, later observed assessments of the same woman re-entered the analysis, the event was assigned to the first assessment at which formula was the sole milk source, and follow-up ended at the last assessment with any breast milk; under this available-visit scheme an event occurring during a missed interval is recorded at the next observed assessment, so event timing may be shifted late. Three sensitivity analyses addressed the observation scheme: censoring at the first missed assessment, excluding women who re-entered after a missed assessment, and excluding the nine women with a later breast-milk record after a formula-only record. The available-visit analysis was retained as primary because attendance was itself selective (women observed through six months were more often primiparous), so censoring at the first missed assessment does not remove dependence between observation and feeding status while discarding observed events; it also matches how feeding status is ascertained in routine care, where a woman who misses one visit and returns is not lost to the service; the close agreement between the primary and interval-censored estimates supports this choice; as a further check, a formal interval-censored analysis bracketed each event between the last assessment with any breast milk and the first with formula only, maximizing a likelihood with interval-specific event probabilities over the same covariates. For women whose first formula-only record followed one or more missed assessments, the likelihood contribution summed the transition probabilities across all intervals between the last observed

breast-milk record and the first formula-only record; women without an observed event contributed the survival probability through their last observed assessment. Interval-specific baseline logits and common covariate coefficients were estimated by maximum likelihood with quasi-Newton optimization. Covariates were prespecified on clinical grounds and prior literature rather than by univariable screening. Model A adjusted the baseline EPDS indicator for cesarean delivery, primiparity, and maternal age; Model B added postpartum care-center use; Model C used the time-varying recent EPDS indicator and the lagged mastitis indicator with the same obstetric covariates. For feeding category, the primary model contrasted breast-milk-only with mixed feeding, the three-category model contrasted direct and expressed feeding with mixed feeding, and a within-breast-milk-only model contrasted direct with expressed feeding, each adjusted for cesarean delivery, primiparity, maternal age, and care-center use; further sensitivity models separately added gestational age and birth weight, body mass index, and the first-week EPDS score as a continuous covariate, the last acknowledging its contemporaneous measurement with feeding. To assess the parity estimate without and with feeding category on an identical sample, nested models were fitted on the complete-case person-periods of the primary contrast. The assumption of a common feeding-category association across intervals was assessed with likelihood-ratio tests for feeding category by interval interaction, conventional (likelihood-ratio chi-square 14.75 on 6 degrees of freedom) and based on Firth penalized likelihood (chi-square 13.53 on 6 degrees of freedom; robust to zero-event cells), with Firth-penalized interval-specific estimates and profile penalized-likelihood confidence intervals where events were sparse; all models were implemented directly in Python 3.12 (NumPy 2.4.4, SciPy 1.17.1) using purpose-written Newton-Raphson routines and the heterogeneity assessment regarded as exploratory; because of its smaller number of events, the within-breast-milk-only comparison was treated as exploratory and additionally fitted with reduced adjustment sets and with Firth penalized likelihood. Analyses were complete-case within each model, with person-period, event, and women counts reported per model; the contribution of each covariate to complete-case exclusion is reported in the Results. To characterize attrition, women with six-month information (an observed six-month assessment or an earlier event) were compared with women censored earlier. Analyses used Python 3 with a purpose-written Newton-Raphson maximum-likelihood routine (convergence when the maximum absolute coefficient update fell below $1e-10$), verified against the binomial generalized linear model in statsmodels (Python) to machine precision (maximum coefficient difference $4.3e-15$). Firth-penalized point estimates and the penalized-likelihood ratio test were computed in Python and cross-checked against the R package logistf (version 1.26.1, R 4.3.3), which agreed on all point estimates and on the interaction test statistic; the profile penalized-likelihood confidence intervals reported for interval-specific estimates were obtained with logistf; the analysis code and the de-identified individual-level analytic dataset are available from the corresponding author subject to institutional approval and a data-use agreement, as the data derive from clinical records governed by the approving institutional review board.

Ethics

The study was approved by the Taipei Medical University Joint Institutional Review Board (TMU-JIRB approval No. N202512016), which covers analyses of infant-feeding outcomes in this cohort; the

requirement for informed consent was waived for this retrospective analysis of routinely collected data.

Results

Cohort

Of 1,562 women in the follow-up program, 894 had a feeding record at any assessment during the collection period, 762 had a feeding record at one week, 705 could be linked to delivery records with one pregnancy retained per woman, and 651 were providing any breast milk at one week and formed the risk set (Fig. 1). Of these, 58 (8.9%) had no feeding assessment after the first week, because they did not take part in the later surveys, and contributed no person-periods; a further 89 missed the one-month assessment but were observed at later visits and re-entered the risk set under the censoring rule. At one week, 72 women (11.1%) were directly breastfeeding, 47 (7.2%) were feeding expressed breast milk, and 532 (81.7%) were mixed feeding. Baseline characteristics by six-month outcome status (first formula-only record, $n = 318$; no formula-only record through six months, $n = 172$; censored earlier, $n = 161$) are shown in Table 1: first-week feeding category and parity differed across groups, gestational age differed slightly although the absolute difference was small, and age, body mass index, birth weight, cesarean delivery, care-center use, and first-week EPDS did not differ materially. Baseline characteristics by first-week feeding category are shown in Additional file 1: Table S2; the three feeding categories differed overall in primiparity and first-week EPDS score (both global $p < 0.001$); descriptively, the direct-breastfeeding group had the lowest primiparity proportion and the lowest mean EPDS score, and the remaining characteristics showed no clear differences.

Table 1
Baseline characteristics by six-month outcome status (n = 651).

Maternal age, years, mean (SD)	First formula-only record (n = 318)	No formula-only record through six months (n = 172)	Censored earlier (n = 161)	p
	33.6 (4.6)	33.8 (4.0)	33.8 (4.4)	0.62
Body mass index, kg/m ² , mean (SD)	27.1 (4.0)	27.5 (4.0)	27.1 (4.2)	0.33
Gestational age, weeks, mean (SD)	38.1 (1.5)	38.3 (1.4)	38.0 (1.4)	0.045
Birth weight, kg, mean (SD)	3.0 (0.4)	3.0 (0.4)	3.0 (0.5)	0.84
Primiparous, n (%)	224 (70.9)	109 (63.7)	83 (55.0)	0.003
Cesarean delivery, n (%)	123 (38.7)	50 (29.1)	59 (36.6)	0.10
High-risk designation, n (%)	142 (44.7)	67 (39.0)	70 (43.5)	0.47
Postpartum care center at first week, n (%)	263 (83.0)	139 (81.3)	127 (79.4)	0.63
EPDS at first week, mean (SD)	3.3 (3.5)	3.0 (3.8)	3.5 (3.9)	0.30
EPDS ≥ 10 at first week, n (%)	17 (5.6)	10 (6.2)	12 (8.2)	0.56
Direct breastfeeding at one week, n (%)	12 (3.8)	41 (23.8)	19 (11.8)	< 0.001
Expressed breast milk at one week, n (%)	19 (6.0)	22 (12.8)	6 (3.7)	0.003
Breast-milk-only at one week, n (%)	31 (9.7)	63 (36.6)	25 (15.5)	< 0.001
Values are n (%) or mean (SD); denominators vary with item-level missingness (EPDS at first week available for 611 women). Groups: first formula-only record during follow-up; no formula-only record observed through six months; censored before six months without an observed formula-only record. p from chi-square (categorical) or Kruskal-Wallis (continuous) tests across the three groups; these p values are descriptive and were not used for covariate selection. High-risk designation: delivery-record flag assigned by the treating obstetrician for obstetric or medical risk factors. EPDS, Edinburgh Postnatal Depression Scale.				

Timing of the transition

During observed follow-up, 318 first formula-only records were identified across 1,511 evaluable person-periods (48.9% of the baseline cohort of 651, a denominator that includes the 161 women censored early); under the life-table observation and censoring assumptions, the estimated cumulative incidence

by six months was 64.7%. The life-table probability of remaining free of a first formula-only record was 88.3% at one month, 70.6% at two months, 48.2% at four months, and 35.3% (95% CI 31.1–39.5) at six months (Table 2, Fig. 2). Per interval, the hazard was 11.7% (95% CI 9.2–14.8) between one week and one month, 20.1% (16.5–24.2) between one and two months, 31.6% (27.0–36.7) between two and four months, and 26.8% (21.6–32.8) between four and six months; because the last two intervals span two months, the monthly-equivalent event-probability point estimate was numerically highest from one to two months (20.1%, 16.5–24.2, versus 17.3%, 14.6–20.4, and 14.4%, 11.4–18.0, on the monthly-equivalent scale, with overlapping confidence intervals), whereas the largest raw event count occurred during the longer two-to-four-month interval (112 of 318, 35.2%); monthly equivalents assume a constant monthly conditional hazard within each multi-month interval (Table 2). Cross-sectionally, among women with a feeding record at each visit and irrespective of prior events, any breast-milk feeding was reported by 445 of 504 (88.3%), 335 of 459 (73.0%), 249 of 463 (53.8%), and 177 of 415 (42.7%) attendees. Among the 415 women assessed at six months, 177 (42.7%) provided any breast milk: 172 had remained free of a formula-only record and 5 had a prior formula-only record followed by resumption of breast milk (9 such resumptions occurred across the whole follow-up). This cross-sectional prevalence is not directly comparable with the life-table event-free probability because the denominators and estimands differ.

Table 2
Life table of the first formula-only record (available-visit analysis).

Interval	Evaluable person-periods	Events	Eligible, not assessed	Re-entered after missed visit	Hazard % (95% CI)	Monthly-equivalent % (95% CI)	Free of formula-only record % (95% CI)
1 week-1 month	504	59	147	0	11.7 (9.2–14.8)	11.7 (9.2–14.8)	88.3 (85.2–90.8)
1–2 months	418	84	174	56	20.1 (16.5–24.2)	20.1 (16.5–24.2)	70.6 (66.3–74.4)
2–4 months	354	112	154	63	31.6 (27.0–36.7)	17.3 (14.6–20.4)	48.2 (43.8–52.6)
4–6 months	235	63	161	33	26.8 (21.6–32.8)	14.4 (11.4–18.0)	35.3 (31.1–39.5)
Evaluable person-periods: women without a prior event who attended the assessment ending the interval; under the available-visit scheme, women eligible but not assessed contribute no person-period for that interval and re-enter at their next observed assessment. Hazard: per-interval event probability with Wilson 95% CI. Re-entered after missed visit counts interval-specific records, not unique women. Monthly-equivalent values assume a constant monthly conditional hazard within each multi-month interval; their confidence intervals are obtained by applying the same transformation to the interval limits. Free of formula-only record: life-table probability of remaining free of a first formula-only record, with log(-log) 95% CI.							

Associations with the transition

In the primary contrast, breast-milk-only feeding at one week was associated with lower adjusted conditional odds of a first formula-only record than mixed feeding (OR 0.21, 95% CI 0.14–0.33). In the three-category model (reference, mixed feeding), the adjusted OR was 0.14 (0.08–0.26) for direct breastfeeding and 0.34 (0.20–0.59) for expressed breast milk (common-effect summaries constrained to be constant across intervals, to be read alongside the interval-specific estimates); within breast-milk-only feeding, direct feeding was associated with lower odds than expressed feeding (OR 0.37, 0.16–0.85, $p = 0.019$), suggesting that feeding route may carry information beyond the presence of formula. Cesarean delivery was associated with higher odds (adjusted OR 1.49, 1.12–1.97) and older age with lower odds (OR 0.66 per 10 years, 0.47–0.91); no statistically clear association with care-center residence was detected (OR 0.95, 0.67–1.36), and the confidence interval does not exclude potentially relevant effects. In nested models on the identical complete-case sample, the primiparity estimate was 1.27 (0.96–1.69) without feeding category and 0.96 (0.71–1.29) with it; this indicates substantial statistical overlap between parity and first-week feeding status; because of odds-ratio non-collapsibility and residual confounding it should not be read as evidence of mediation. Neither the baseline EPDS indicator (adjusted OR 0.90, 0.52–1.58) nor the time-varying recent EPDS indicator (OR 1.47, 0.87–2.47) showed statistically clear evidence of association, the latter compatible with effects up to an OR of 2.5; the lagged mastitis indicator was likewise inconclusive (OR 0.79, 0.43–1.44) (Table 3). A likelihood-ratio test indicated that the magnitude of feeding-category associations varied across intervals ($p = 0.022$; Firth penalized-likelihood ratio test, robust to the zero-event cells, $p = 0.035$) while remaining directionally consistent: Firth-penalized interval-specific ORs with profile penalized-likelihood intervals for direct breastfeeding were 0.05 (< 0.001 –0.38), 0.08 (0.008–0.29), 0.19 (0.073–0.42), and 0.28 (0.095–0.67), and for expressed breast milk 0.42 (0.084–1.30), 0.04 (< 0.001 –0.28), 0.47 (0.196–1.03), and 0.63 (0.242–1.50) (Additional file 1: Table S1); no first formula-only record occurred among directly breastfeeding women before one month (0 of 58 evaluable person-periods), and the pooled estimates are therefore common-effect summaries constrained to be constant across intervals; for direct breastfeeding the association was strongest in the earliest intervals, whereas the pattern for expressed feeding was irregular. This heterogeneity assessment is exploratory. Given 29 events, the within-breast-milk-only contrast is exploratory: the direct-versus-expressed estimate was 0.33 crude (time-adjusted), 0.35 minimally adjusted, 0.37 fully adjusted, and 0.39 (0.18–0.85) with Firth penalization.

Table 3
Adjusted odds ratios for a first formula-only record.

Model / variable	OR	95% CI	p	Person-periods / events / women
Model D (primary): breast-milk-only vs mixed				1,487 / 315 / 578
Breast-milk-only at one week	0.21	0.14–0.33	< 0.001	
Cesarean delivery	1.51	1.14-2.00	0.004	
Primiparity	0.96	0.71–1.29	0.79	
Maternal age (per 10 years)	0.65	0.47–0.90	0.010	
Postpartum care center	0.95	0.66–1.35	0.76	
Model D (three-category): reference mixed feeding				1,487 / 315 / 578
Direct breastfeeding at one week	0.14	0.08–0.26	< 0.001	
Expressed breast milk at one week	0.34	0.20–0.59	< 0.001	
Cesarean delivery	1.49	1.12–1.97	0.006	
Primiparity	0.95	0.70–1.28	0.73	
Maternal age (per 10 years)	0.66	0.47–0.91	0.011	
Postpartum care center	0.95	0.67–1.36	0.78	
Model D (within breast-milk-only): direct vs expressed				348 / 29 / 107
Direct breastfeeding (vs expressed)	0.37	0.16–0.85	0.019	
Cesarean delivery	0.84	0.33–2.12	0.71	
Primiparity	1.39	0.60–3.20	0.44	
Maternal age (per 10 years)	0.65	0.24–1.76	0.40	
Postpartum care center	1.83	0.56–5.98	0.32	
Model A: baseline EPDS				1,416 / 302 / 548
EPDS ≥ 10 (first week)	0.90	0.52–1.58	0.72	
All models include indicator variables for the four risk intervals; all covariates in each model are shown. OR, conditional odds ratio for a first formula-only record within an interval, with the covariate effect constrained to be common across intervals, with Wald 95% CI; women, unique women contributing person-periods to the model. Sensitivity analyses for the observation scheme and for gestational age and birth weight are reported in the text. EPDS, Edinburgh Postnatal Depression Scale.				

Model / variable	OR	95% CI	p	Person-periods / events / women
Cesarean delivery	1.35	1.02–1.79	0.034	
Primiparity	1.38	1.03–1.84	0.029	
Maternal age (per 10 years)	0.87	0.63–1.20	0.40	
Model B: baseline EPDS + care center				1,410 / 301 / 545
EPDS > = 10 (first week)	0.91	0.52–1.59	0.74	
Postpartum care center	1.04	0.72–1.50	0.84	
Cesarean delivery	1.38	1.05–1.83	0.023	
Primiparity	1.34	1.00–1.80	0.053	
Maternal age (per 10 years)	0.86	0.62–1.20	0.38	
Model C: time-varying EPDS + lagged mastitis				1,443 / 305 / 560
Recent EPDS > = 10 (time-varying)	1.47	0.87–2.47	0.15	
Mastitis before interval (lagged)	0.79	0.43–1.44	0.44	
Cesarean delivery	1.35	1.02–1.78	0.037	
Primiparity	1.35	1.01–1.80	0.041	
Maternal age (per 10 years)	0.81	0.59–1.12	0.20	
All models include indicator variables for the four risk intervals; all covariates in each model are shown. OR, conditional odds ratio for a first formula-only record within an interval, with the covariate effect constrained to be common across intervals, with Wald 95% CI; women, unique women contributing person-periods to the model. Sensitivity analyses for the observation scheme and for gestational age and birth weight are reported in the text. EPDS, Edinburgh Postnatal Depression Scale.				

Associations of feeding category remained inverse across observation schemes, with estimates for direct breastfeeding strengthening and those for expressed breast milk modestly attenuated: censoring at the first missed assessment gave adjusted ORs of 0.10 (0.04–0.23) for direct and 0.41 (0.23–0.74) for expressed feeding; excluding women who re-entered after a missed assessment gave 0.10 (0.04–0.22) and 0.40 (0.22–0.71); and excluding the nine women with a later breast-milk record gave 0.14 (0.08–0.26) and 0.35 (0.20–0.60). Adding gestational age and birth weight left the estimates essentially unchanged (0.14 and 0.33), and neither covariate was associated with the outcome. In the interval-censored analysis, which brackets each event between the last breast-milk and first formula-only assessments, adjusted ORs were 0.16 (0.08–0.29) for direct and 0.37 (0.22–0.63) for expressed feeding; under permanent censoring at the first missed visit, the life-table cumulative incidence by six months

was 57.2% (woman-level bootstrap 95% CI 52.8–62.2; 1,000 resamples of women, each resampled woman contributing her entire visit history) compared with 64.7% (60.6–69.2) in the primary analysis, illustrating sensitivity of the absolute risk to the observation scheme; the life-table confidence intervals do not reflect uncertainty from intermittent missingness and re-entry. Of 651 women, 58 contributed no person-periods; among the 593 contributors, covariate missingness excluded 15 from the primary model (parity missing in 12, care-center status in 3), leaving 578 women, and refitting without the care-center covariate included 581 women with ORs of 0.14 (0.07–0.25) and 0.37 (0.22–0.63), and adding body mass index (missing in three women) likewise left the estimates unchanged (0.14 and 0.34; body mass index OR 1.00, 0.97–1.04), and adding the first-week EPDS score as a continuous covariate likewise left them unchanged (0.15 and 0.36; EPDS OR 1.01 per point, 0.97–1.04).

Attrition

Of the 651 initiators, 490 had six-month information (an observed six-month assessment or an earlier event) and 161 were censored earlier, comprising the 58 women with no post-baseline assessment and 103 censored after partial follow-up. Women with six-month information were more often primiparous (68.4% versus 55.0%, $p = 0.003$); age, cesarean delivery, care-center use, and first-week EPDS did not differ materially.

Discussion

In this hospital follow-up cohort of women providing any breast milk at one week, 318 first formula-only records were observed during follow-up, with a life-table cumulative incidence of 64.7% by six months; the monthly-equivalent event-probability point estimate was numerically highest between one and two months while the largest raw event count fell in the longer two-to-four-month interval; interestingly, this period overlaps the end of statutory eight-week maternity leave in Taiwan [14], although individual return-to-work dates were unavailable and the temporal correspondence is hypothesis-generating. First-week feeding category showed a strong association with the outcome, and the common-effect summaries showed an ordered gradient, with direct breastfeeding having the lowest odds, expressed breast-milk feeding intermediate odds, and mixed feeding the highest, robust to adjustment for cesarean delivery, parity, age, care-center use, gestational age, and birth weight; the magnitude of these associations varied across follow-up intervals (interaction $p = 0.022$; penalized-likelihood test $p = 0.035$), with a clear early-to-late attenuation for direct breastfeeding and an irregular pattern for expressed breast milk. An earlier discrete-time survival analysis of low-income women in the United States likewise found the risk of cessation concentrated in the first months [15]; in the present cohort the burden of transitions extended well into the two-to-four-month interval, underscoring that the vulnerable period extends beyond the immediate puerperium.

A distinctive feature of the cohort is its baseline composition: 81.7% of the cohort was already combining breast milk with formula at one week and only 11.1% were feeding directly at the breast. The high prevalence of mixed feeding in this cohort is consistent with the continuing challenges in sustaining

exclusive breastfeeding reported in Taiwan [16]; intensive marketing of commercial milk formula is one proposed contributor [17]. This composition has two consequences for interpretation: the absolute event-free estimates should be compared with other cohorts cautiously, and the feeding-category associations were estimated with mixed feeding as the reference group, a clinically relevant group for early lactation support; the within-breast-milk-only contrast provides exploratory evidence that feeding route carries information beyond early formula exposure, although with 107 women and 29 events this estimate is imprecise.

Two features of these results bear emphasis. First, the feeding-category associations should be read as early markers rather than demonstrated causal effects: by one week, feeding category already reflects the accumulated experience of latching, supply, infant behavior, and maternal preference, so the direct-feeding group is partly self-selected for feeding that is going well. We therefore position feeding category as a clinical early marker for identifying women who may benefit from support, not as an estimate of the causal effect of feeding route; the near-absence of early transitions among directly breastfeeding women is consistent with this marker reading. In particular, the strong association for mixed feeding is expected rather than novel, since women already using formula at one week are closer to the endpoint along the feeding trajectory; that estimate quantifies baseline position on the trajectory rather than a new prognostic discovery. Even so, first-week feeding category is routinely available clinical information in every service that records feeding at an early visit. Its usefulness as a formal prognostic tool, including discrimination, calibration, and external validity, was not evaluated in this study. Second, the marked change in the primiparity coefficient after inclusion of feeding category suggests substantial statistical overlap between parity and first-week feeding status; because of odds-ratio non-collapsibility and residual confounding, this should not be interpreted as evidence of mediation. Two mechanisms lend the associations plausibility. The cesarean association is consistent with the higher risk of delayed onset of lactogenesis II reported in a systematic review and meta-analysis of Chinese women [18], and with evidence that immediate skin-to-skin contact, which operative birth commonly delays, supports breastfeeding across modes of birth [19]; both suggest the early postoperative period as a candidate window for the excess risk, a hypothesis this study cannot test. For parity, breastfeeding self-efficacy and observed technique, which recent work links jointly to depressive symptoms and breastfeeding success [20], are concentrated among, and modifiable in, first-time mothers, offering a plausible substrate for the attenuation observed in the nested models, without establishing mediation.

For depressive symptoms, whether at baseline or as the most recent score, no statistically clear association with the first formula-only record was detected in this cohort and clinically relevant effects cannot be excluded, with the time-varying estimate compatible with effects as large as an odds ratio of 2.5; the relationship may also run in both directions, since difficulty establishing feeding can itself depress mood, and covariates updated only at scheduled visits may not capture such short-term reciprocal influences. For postpartum care-center residence, sometimes suspected of facilitating early formula supplementation, no statistically clear association with a first formula-only record was detected, and the confidence interval does not exclude potentially relevant effects. Mastitis was analyzed with a lagged indicator so that exposure ascertainment preceded each interval; even so, only women still

providing breast milk can report mastitis, and the inconclusive estimate is not interpreted further. The absence of an association for care-center residence also does not preclude effects of practices within centers: in a Taiwanese postpartum care center, rooming-in was associated with longer exclusive breastfeeding among first-time mothers [21], suggesting that what happens inside the center, rather than residence itself, may be the actionable variable.

Practical implications follow at two time points. In the first week, the pooled gradient across feeding categories supports using first-week feeding status to prompt assessment of feeding difficulties and preference-sensitive lactation support before discharge and at the one-week visit; women already using formula or relying on expressed milk may represent particularly relevant groups for such assessment, without implying that feeding route itself is causal; competency-based training of nursing staff has been shown to improve breastfeeding counseling [22], and in this program the one-week visit already exists for wound assessment, so existing first-week visits could be used to assess feeding difficulties and offer preference-sensitive support aligned with each woman's goals; because most women in this setting are already mixed feeding at one week, sustaining combined feeding rather than a return to exclusive breast-milk feeding may be the more realistic aim for that majority, although whether such support changes feeding outcomes was not tested. Around the end of statutory maternity leave, when the monthly-equivalent point estimate is numerically highest and the largest raw event count follows, these findings support anticipatory lactation guidance from before one month through four months; workplace accommodation and maternity-protection policies are plausible complementary strategies, although employment and return-to-work timing were not measured [23].

Strengths of the study include feeding status recorded repeatedly within routine care at five closely specified time points, an event definition corroborated by an independently coded program indicator, linkage to measured obstetric covariates, and a formal interval-censored sensitivity analysis. Several limitations follow from the design. The feeding items were collected in the program only between November 2021 and September 2024, so the cohort is bounded by the collection period rather than by attrition; within the cohort, censoring before six months was nonetheless appreciable (161 of 651, including 58 women with no assessment after the first week because they did not take part in the later surveys) and selective for parity; because non-attendance may itself relate to feeding status, the assumption of non-informative censoring cannot be verified, and the absolute event-free estimates depend on assumptions about the observation process and may be affected by informative missingness; the high prevalence of mixed feeding at one week (81.7%) reflects this cohort's feeding pattern and further limits transportability of absolute risk estimates. Feeding categories were recorded by nurses at discrete visits without quantities, exclusivity of breastfeeding between visits cannot be established, and the timing of transition is interval-censored between assessments and, under the available-visit scheme, an event during a missed interval is recorded only at the next observed assessment; inverse-probability-of-censoring weighting was not undertaken, and the formal interval-censored analysis and concordant sensitivity analyses only partly address dependence between attendance and feeding status. Household income, occupation, and return-to-work dates were unavailable, so the interpretation of the clustering of transitions around the end of statutory maternity

leave as a return-to-work phenomenon remains circumstantial. Data on neonatal intensive-care admission, infant illness, medically indicated supplementation, and maternal feeding intention were unavailable and are potential confounders of the feeding-category associations. Finally, this is a single-center cohort in a setting with high postpartum care-center use, and absolute rates may not generalize to populations with different socioeconomic profiles.

Conclusions

Under the available-visit analysis, first formula-only records were concentrated in the first four postpartum months, with the monthly-equivalent point estimate numerically highest from one to two months. The common-effect summaries showed an ordered gradient from direct breastfeeding through expressed breast milk to mixed feeding, but associations varied across intervals, with clear early-to-late attenuation for direct breastfeeding and an irregular pattern for expressed breast milk; the observational design and category composition preclude causal interpretation of feeding route; cesarean delivery remained associated with the outcome after adjustment for measured covariates, and depressive symptoms, mastitis, and care-center use showed no statistically clear evidence of association. Feeding status recorded at the first-week visit may help clinicians recognize feeding trajectories that warrant discussion and preference-sensitive lactation support, beginning before one month and continuing through four months; it was not evaluated as a formal prediction instrument.

Abbreviations

CI
confidence interval
EPDS
Edinburgh Postnatal Depression Scale
OR
odds ratio
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
TMU-JIRB
Taipei Medical University Joint Institutional Review Board.

Declarations

Ethics approval and consent to participate

The study was approved by the Taipei Medical University Joint Institutional Review Board (TMU-JIRB approval No. N202512016) with a waiver of informed consent for this retrospective analysis of routinely collected data. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Additional file

Additional file 1: Supplementary tables (Microsoft Word .docx). Table S1, Firth-penalized interval-specific odds ratios for first-week feeding category; Table S2, baseline characteristics by first-week feeding category; Table S3, observation-scheme sensitivity analyses; Table S4, covariate-adjustment sensitivity analyses.

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Author Contribution

SYC contributed to the conception and design of the study, performed the statistical analyses, and interpreted the data. SPM carried out the clinical implementation of the follow-up program, collected and curated the data, drafted the manuscript, and finalized it for submission. Both authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed contain protected health information and are not publicly available; the de-identified individual-level analytic dataset and analysis code are available from the corresponding author on reasonable request, subject to institutional approval and a data-use agreement.

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Figures

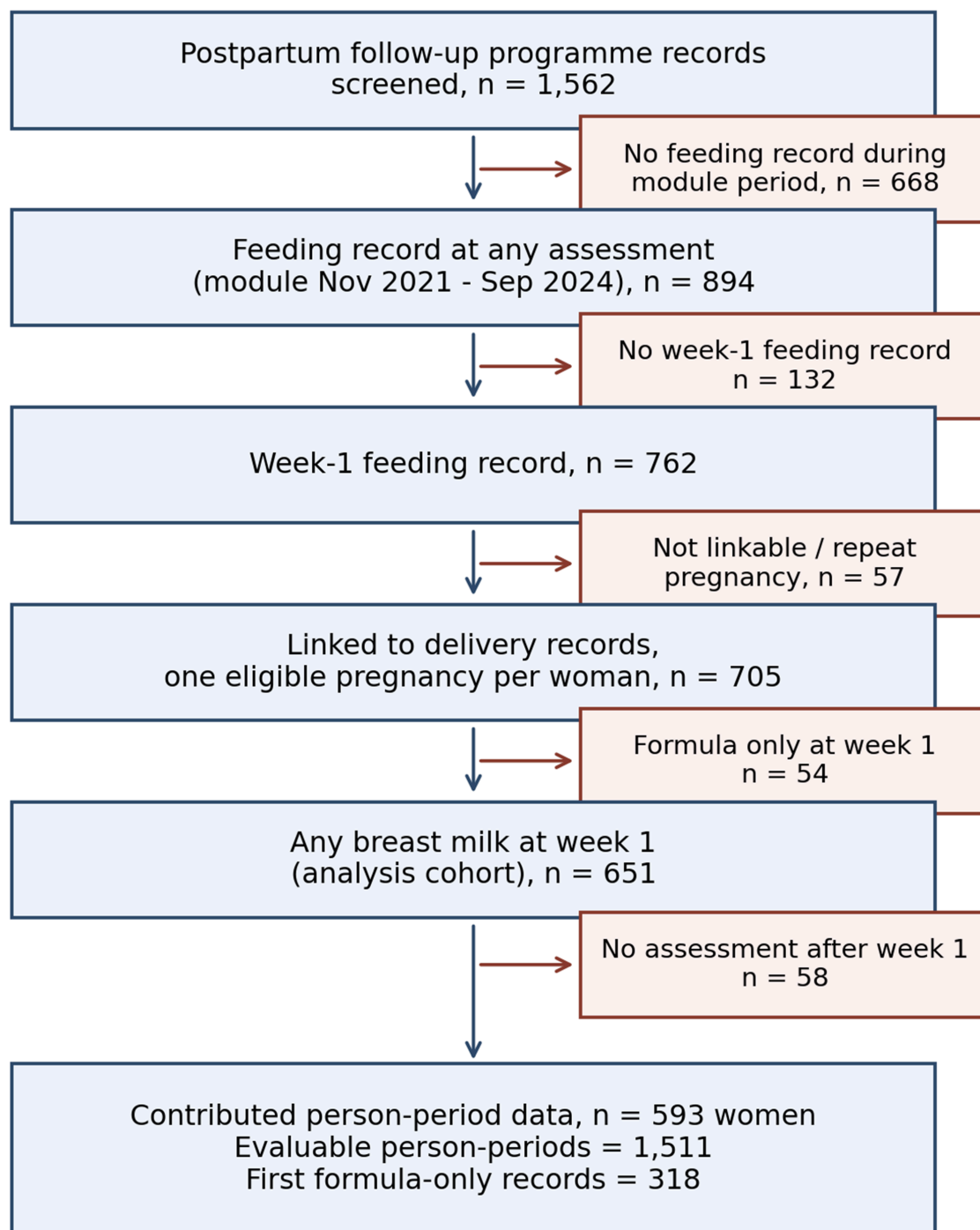


Figure 1

Participant flow through the study. Numbers at each step are women; the final box gives the number contributing person-period data, the evaluable person-periods, and the first formula-only milk-feeding records. The first box represents the full follow-up-program database; infant-feeding data were available only during November 2021 to September 2024.

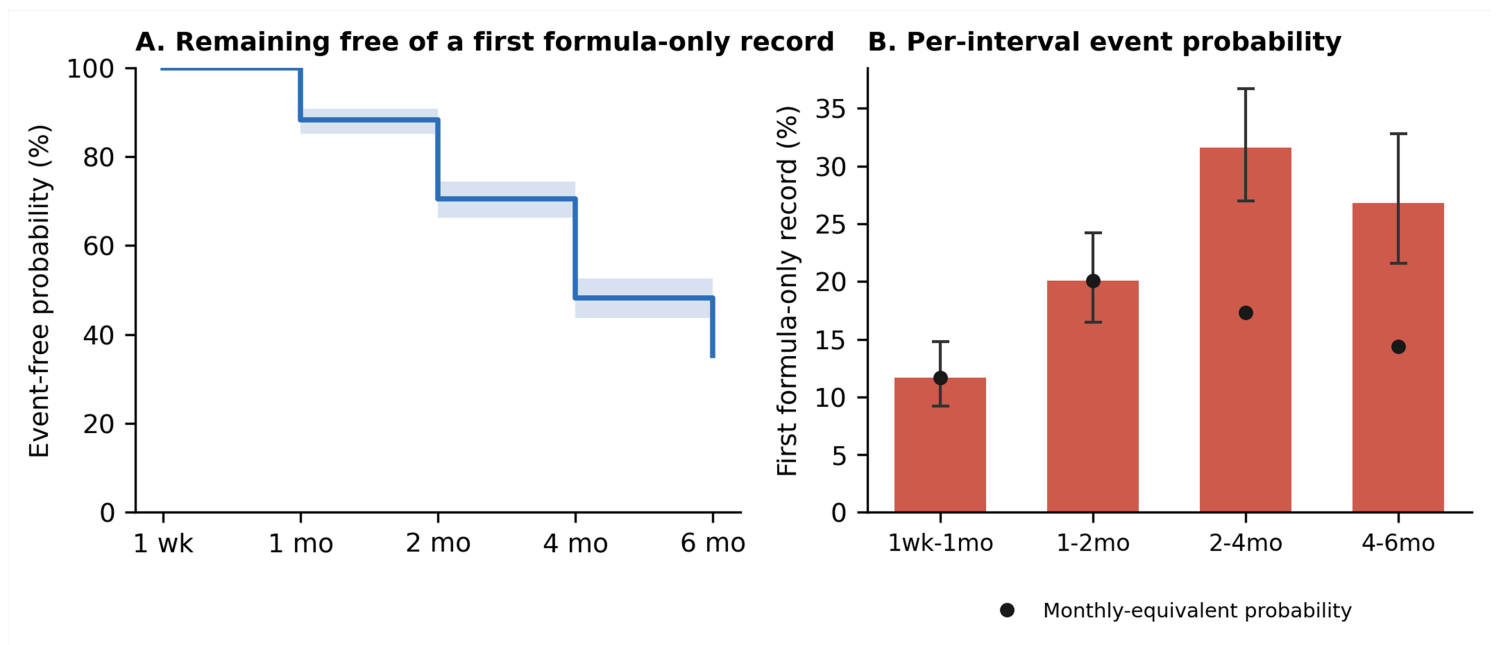


Figure 2

Event-free probability and per-interval event probability. Life-table probability of remaining free of a first formula-only milk-feeding record (A) and per-interval probability of a first formula-only milk-feeding record (B; bars, per-interval event probability with 95% CI; markers, monthly-equivalent point estimates assuming a constant monthly conditional hazard within each interval) among women providing any breast milk at one week (n = 651).

Supplementary Files

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