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# CONTINUOUSLY RECORDED SUCKLING BEHAVIOUR AND ITS EFFECT ON LACTATIONAL AMENORRHOEA

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**Summary.** The hypothesis that the month-specific rate of return to ovarian cyclicity after childbirth is causally related to suckling pattern was tested for a population of New Mexican women recruited within the service area of New Mexico Highlands University and for a nationwide USA subpopulation of women recruited through membership of the Couple to Couple League (CCL). Survival analysis for time-dependent covariates was used, and significant predictors of the first postpartum menses were found. Important differences were detected in the suckling pattern for the two groups and a 5:2 differential was found in their respective rates of menstrual cycle recovery. Although the two groups were comparable perinatally, daily and time-windowed breast-feeding performance fell off at twice the rate for the New Mexico population when contrasted with the CCL sample. For both populations, the introduction of solid feeds was a strong and significant predictor of returning menstrual cyclicity, independent of suckling pattern.

## Introduction

This study tests the hypothesis that the pattern of suckling behaviour throughout the day and night significantly affects the timing of postpartum menstrual cycle recovery. Unprecedented time-varying and detailed suckling data were obtained from two groups of mothers in the USA using Event Recorder technology (Taylor, Lujan & Vázquez-Geffroy, 1995). The first group comprised 42 mothers residing in north-eastern New Mexico. These were recruited from local clinics and nutritional outreach programmes. The second group of 144 mothers was recruited nationwide through the Couple to Couple League International (CCL), an organization dedicated to providing instruction about natural family planning and ecological breast-feeding.

‘Ecological breast-feeding’ is similar to the standard definition of exclusive or almost-exclusive breast-feeding for the first 6 months after childbirth (Labbock & Krasovec, 1990). However, according to CCL co-founder Sheila Kippley, who coined the phrase, ecological breast-feeding also refers to a mothering style typified by mother–baby togetherness with (1) frequent nursing both day and night (2) pacification at the breast without the use of soothers, (3) absence of scheduled feedings and babysitters, and (4) continued breast-feeding for several years (Kippley, 1974, 1989). This type of breast-feeding is often associated with the postpartum suppression of menses known as 'lactational amenorrhoea' (Kippley & Kippley, 1977).

While a wide range of breast-feeding behaviours would be expected to be exhibited by each group, it is presumed that the local New Mexico sample is typical of local populations anywhere in the USA. Generally, American mothers may be likely to supplement their nursing activity with bottle-feeding to engage in economic, social and other activities away from the baby and to develop additional patterns of early separation from the child that could effect an early return of fertility. At the other extreme, the CCL group would be expected to include women who are ecological breast-feeders. Some of these, perhaps, might approach the limits of extended lactational amenorrhoea.

## Background

Prospective breast-feeding studies have shed light on the relationship between suckling and ovarian quiescence after childbirth. These include a study at Monash University that showed a mean of 10·6 months anovulation and 9·5 months amenorrhoea for a group of 89 Australian women who were breast-feeding their babies (Lewis *et al.*, 1991). In an earlier study (Taylor, Smith & Samuels, 1991) a life table median of 12·8 months for the duration of postpartum anovulation among a group of 72 mothers from the USA membership of the Couple to Couple League was reported.

Several studies have used an epidemiological statistic generated from hazard analysis (Jones & Pallone, 1994; Zohoori & Popkin, 1996). Identified variables, which may change over time, were tested as to their predictive value for the interval of recurrence of ovulation and menses following childbirth. A study at the University of California Davis (Heinig *et al.*, 1994) elucidated the effect of formula-feeding on the rate of postpartum menstrual cycle recovery. Jones (1988) found a dose-dependent relationship between suckling stimulus and the postpartum resumption of menses. In an earlier study (Taylor *et al.*, 1991), a significant relationship was found between the timing of the first postpartum ovulation and several measures of breast-feeding performance: the suckling frequency ($p<0{\cdot}03$), the interval between suckling bouts ($p<0{\cdot}005$) and the total 24-h suckling duration ($p<0{\cdot}03$), but no statistical significance was found for the median length of an individual bout ($p>0{\cdot}7$).

In a retrospective Chilean study (Diaz *et al.*, 1991), a proportional-hazards model was employed to examine the influence of time postpartum, menstrual status and breast-feeding pattern on the risk of pregnancy. Their findings pointed to the importance of breast-feeding *per se* in delaying pregnancy from unprotected intercourse. The contraceptive significance of lactation was highlighted (Kahn *et al.*, 1989) by a report that in countries such as Pakistan, where contraceptive use is low, active promotion of breast-feeding is needed to prevent its further decline, to maintain its contraceptive effect and to promote well known maternal and child health benefits. Recent analyses of survey data from India (Nath, Land & Singh, 1994) have suggested that breast-feeding's contraceptive effect persists beyond postpartum amenorrhoea. A cross-cultural study of breast-feeding found a postpartum anovulatory interval of 6·2 months for a group of 60 breast-feeding mothers in Baltimore (Eslami *et al.*, 1990). Their counterpart, a breast-feeding group of 41 mothers in Manila, experienced a mean of 8·8 months anovulation. The observations closely correspond to the life tables for menstruation and ovulation in the Monash study.

Postpartum anovulation during lactation may be due to suckling-induced hypothalamic disruption (McNeilly, Tay & Glasier, 1994). A likely causative factor, according to this model, is the suppression of the pulsatile secretion of gonadotropin-releasing hormone (GnRH) necessary for the normal succession of ovulatory events. Although plasma concentrations of follicle stimulating hormone (FSH) may be sufficient in lactating women to induce ovarian follicle growth, the consequent inadequate pulsatile luteinizing hormone (LH) release inhibits follicular oestradiol synthesis. Also, the normal LH surge triggering ovulation may be disrupted by suckling activity, even in the presence of normal follicular growth and oestradiol. The hypothesis that suckling-induced GnRH disruption is a key element in the maintenance of postpartum ovarian quiescence is strengthened by the observation that ovarian cycles can be induced in breast-feeding mothers by exogenous, pulsatile GnRH infusion (Zinaman *et al.*, 1995). On the other hand, it is plausible that other pathways may exist to render the ovaries insensitive to FSH, perhaps those tied to the metabolic demands of lactation.

## Methods

*Study populations*

Pregnant women residing in north-eastern New Mexico were recruited from 1992 to 1995 at health clinics and nutrition programmes. Forty-two mothers started the study and were paid a $25 per month participant stipend. Ages at delivery ranged from 19 to 41 years with a median age of 28·0 years. Twelve per cent were single mothers and the remaining 88% were married or living with male partners. The ethnic mix of the local participants was as follows: 60·7% Hispanics, 35·2% non-Hispanic Whites and 4·1% other. All participants were high school graduates who completed a median of 2·0 years of college or vocational school. For the 29 women from whom financial data were collected, the average family income was $22,448 per year ($17,400 median) with a range of $3648 to $55,000 per year. Five reported full-time employment, seven part-time (including students), and eleven were not employed (Vázquez-Geffroy, 1996). Relevant census data for the study area are summarized in Table 1, listing ethnicity, educational level of women of ages 25–34 and median incomes for families in San Miguel, Mora and Taos counties.

The families of the women in the New Mexico study population ranked slightly below the economic level of the study region. The median age at delivery for the New Mexico participants was 28·0 years, while the median age for women delivering in San Miguel County (location of the Northeastern Regional Hospital) in 1994 was more than 5 years younger at 22·8 years (New Mexico, 1996).

The Couple to Couple League International kindly agreed to publish an advertisement for study participants in the January–February 1995 issue of *CCL Family Foundations*, their bimonthly magazine. Informed consent was obtained from 144 married women who participated without stipend in this part of the study.

**Table 1.** Population data for the New Mexico study area: ethnicity, educational level of women aged 25–34 and median family income for the three counties that comprise the New Mexico study area (1990 census)

| Demographic statistic | San Miguel County | Mora County | Taos County |
|---|---|---|---|
| Ethnicity[a] (percentage of total population) | | | |
| Hispanics | 79·6% | 85·0% | 64·9% |
| Non-Hispanic Whites | 18·2% | 14·4% | 27·7% |
| Others | 2·2% | 0·6% | 7·4% |
| Educational level[b] (women aged 25–34) | | | |
| High school diploma | 86·2% | 81·2% | 87·2% |
| Bachelor’s degree | 15·2% | 12·7% | 11·8% |
| Median family income[c,d] | $21,931 | $18,697 | $21,297 |
| Total population[a] | 25,743 | 4,264 | 23,118 |

[a]US Census Bureau (1990a); [b]US Census Bureau (1990b); [c]US Census Bureau (1990c); Whites (including Hispanics).

**Table 2.** Comparative demographic characteristics of the study populations: ethnicity, median educational level, median family income, percentage employed outside the home and median age at childbirth for 42 north-eastern New Mexico participants and 144 Couple to Couple League study participants

| Demographic statistic | North-eastern New Mexico | Couple to Couple League |
|---|---|---|
| Ethnicity (percentage of study population) | | |
| Hispanics | 60·7% | 4·2% |
| Non-Hispanic Whites | 35·2% | 93·7% |
| Others | 4·1% | 2·1% |
| Median educational level | | |
| Years of college | 2·0 | 4·0 |
| Median family income[a] | $17,400 | $50,000 |
| Percentage employed or studying outside home | | |
| Full-time | 11·9% | 2·8% |
| Part-time | 16·7% | 6·9% |
| Median age at childbirth (years) | 28·0 | 31·1 |

[a]USA median family income was $42,300 in 1996 (US Census Bureau, 1997).

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Demographic statistics for the CCL group are summarized in Table 2 along with the comparable statistics for the New Mexico study population. The largest differences are seen in family income: the CCL families receive more than twice the income of the New Mexico families; and in ethnicity: the CCL mothers are largely non-Hispanic, while most of the New Mexico mothers are of Hispanic heritage.

### *Electronic data recording and processing*

Each mother participating in the project was provided with a programmable scientific calculator running the Event Recorder data collection programme. The Event Recorder programme, written in HP postfix language, has been described elsewhere (Taylor *et al*., 1995). The participants used specially programmed keys on the calculator to enter automatically both the START and STOP of the times of breast-feeding and the occasion of any missed data. Participants also were instructed to enter events of their menstrual history into the electronic record. Behavioural data captured by the Event Recorders were periodically (monthly) uploaded into a desktop computer via the calculator serial port. These data were then processed to yield a set of breast-feeding behavioural statistics (Taylor *et al*., 1995).

The potential exists to record each suckling event, defined as the duration (nearest second) of continuous oral contact with the nipple. Vitzthum's suckling definitions are followed (Vitzthum, 1994a). An *ensemble* of suckling events is defined as suckling events separated by intervals of less than 10 s, while suckling ensembles separated by intervals of less than 60 s define a suckling *session*. For the self-recording protocol of this study, the recording regimen was relaxed from what was technically possible, so that participants were not required to log the switching of sides for suckling or momentary releases of the nipple. Accordingly, suckling sessions were computed from the raw data by joining together all suckling events separated by intervals less than 60 s in duration. Also, all those suckling events logged in the Event Recorder as *missed* breast-feedings were counted. A suckling event for which only the START time or STOP time was recorded was counted as an 'incomplete record'. Next, the following were calculated for each 24-h day: median suckling session *length* (minutes); session *frequency* (number per day); average session *spacing* (hours), calculated as 24 h divided by session frequency; and the total daily session *duration* (hours), estimated by the product of session frequency and average session length. The structure of suckling sessions on the 183rd day after childbirth is presented in Fig. 1 for 24 participants taken from both groups, typifying a wide range of breast-feeding behaviour. Recorded suckling events exceeding 120 min were treated as incomplete records for two distinct suckling sessions.

Thirteen of the 42 New Mexico women participating in the study withdrew before their first postpartum menstruation, giving a censoring rate of 31%. However, all behavioural data from the participants were used in the survival-time analysis, whether or not the menstrual response was censored. The New Mexico analysis was based on 5310 observation days from women who were within their postpartum amenorrhoeic interval. Likewise, 60 of the 144 CCL participants withdrew before their first menses, a censoring rate of 42%. The CCL mothers supplied 39,648 days of data, and included three women who remained amenorrhoeic by the conclusion of the study. The measures of breast-feeding performance described above – length, frequency, spacing and

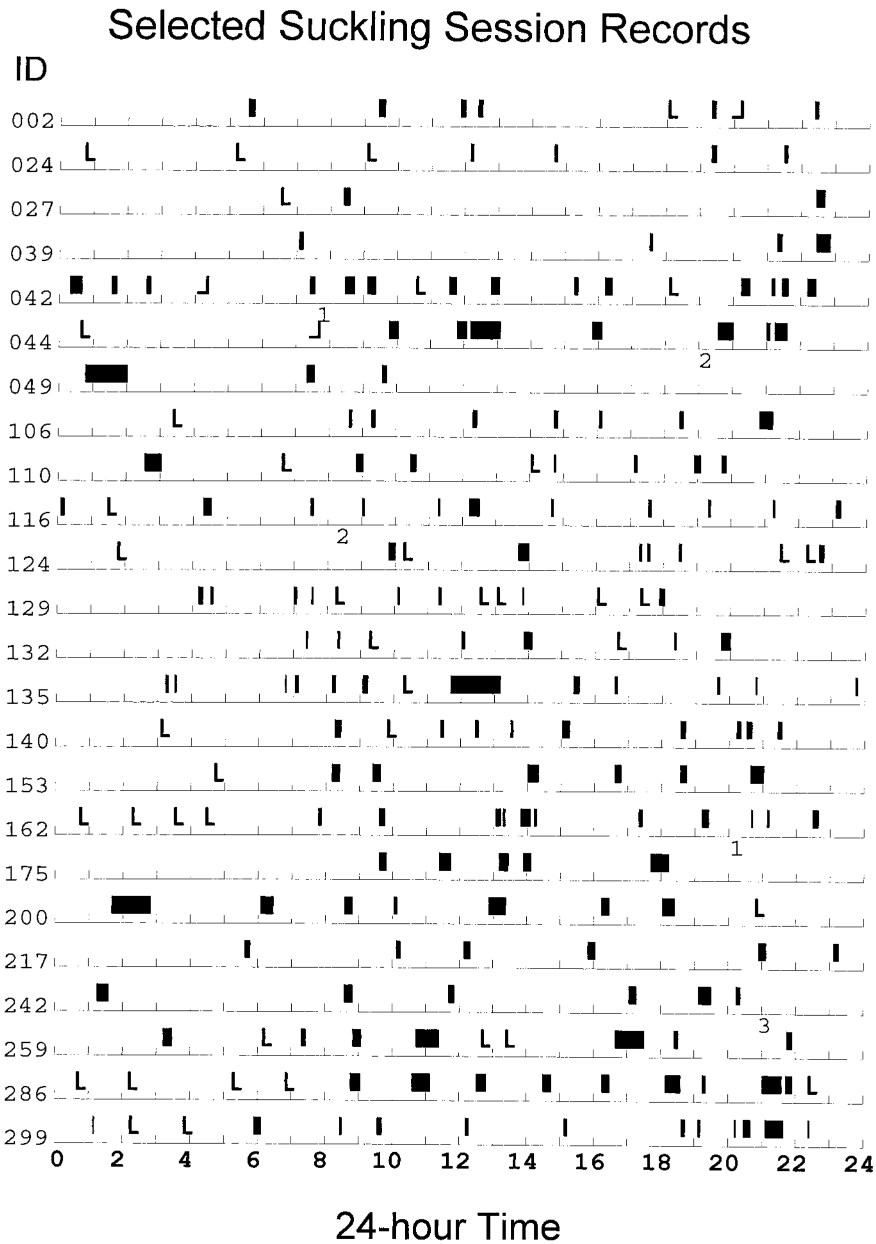


**Fig. 1.** Suckling session patterns for 24 study participants on day 183 after childbirth. Individual suckling sessions are represented by solid rectangles. Sessions for which only the starting time is recorded are represented by 'L' and those for which only the ending time is known, the 'L' is reversed. The number of any missed suckling sessions is displayed by an Arabic numeral at the time they were logged into Event Recorder memory. For this apparently representative sample of study participants, the median suckling session frequency on day 183 was 7·0 sessions per day for the NM participants (#002-049) and 11·0 sessions per day for the CCL participants (#106-299).

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duration – were chosen for survival analysis of postpartum amenorrhoea. With the Cox survival, or proportional hazards, model (Cox & Oakes, 1984), the so-called hazard may be interpreted as the time-specific rate of menstrual cycle recovery after childbirth. The probabilities of continuing without menstruation are computed by Kaplan–Meier product limit estimates.

Daily values exponentially smoothed with a 7-day time constant were used. Physiological justification for the smoothing algorithm lies with the assumption that it is cumulative behaviour of the recent past that influences hypothalamic regulation of postpartum ovarian recrudescence, rather than the suckling activity occurring on the current day postpartum. Theoretically, cumulative suckling behaviour translates to a hypothalamic–mammary 'tone' inversely proportional to the relative risk of menstrual cycle recovery. For any baseline hazard $h_0(t)$, the observed rate of menstruating, $h(t)$, may be proportionally increased or decreased. Accordingly,

$$h(t) = h_0(t)e^{\beta z(t)}$$

where, $z(t)$ is a vector of covariates, possibly time-varying, and $\beta$ is a row vector of coefficients found through maximum likelihood regression.

For each measure of performance, the linear (untransformed) version was tested in a one-covariate Cox model. In addition, the best mathematical transformation for the Cox model was sought by screening 44 'fractional-polynomial' transformations of order two (Royston & Altman, 1994). In addition, all models that contained each pair of the performance measures at a time were assessed. The proportional hazards assumption was checked by testing interactions of time from entry with each covariate. The goodness-of-fit of all models was tested by the STATA implementation of Pregibon's specification link test (Pregibon, 1979). All analyses were carried out with STATA 5.0 (1997).

*Fixed and binary covariates*

Several demographic statistics were used as fixed covariates in proportional hazards models of the time to first postpartum menstruation. These were gathered by questionnaire or home interview and include: *age* (the mother's age in years at childbirth), *parity* (number of births), level of *education* and *family income*. Also tested in the model was *ethnicity* (whether or not the participant indicated Hispanic heritage since this is the dominant ethnic distinction between the two study populations) and *work* (the number of days per week the mother reported work or school outside her home).

The binary covariate *solid feeds* was formed by setting it equal to zero until the first introduction of solid foods to the baby; for subsequent time, it was set equal to unity (Jones & Pallone, 1994). Similarly, the *sleep* covariate assumes a value of unity corresponding to whether and for how many months the mother and baby shared sleep at night. The *bed* covariate was set to a value of unity if shared sleep was reported at any time, and set to zero otherwise.

## Results

The Kaplan–Meier product-limit life table estimates for the return to menstruation for the Couple to Couple League (CCL) and the New Mexico (NM) study populations are

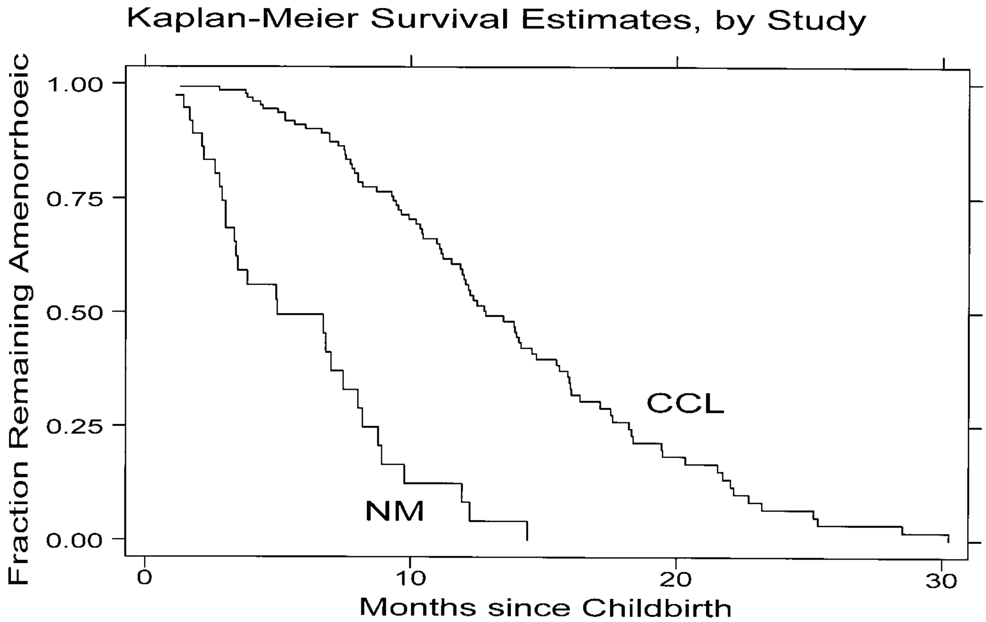


**Fig. 2.** Kaplan–Meier survival estimates for the recurrence of postpartum menstruation among 42 New Mexico (NM) women participating in a study of factors that maintain postpartum amenorrhoea at New Mexico Highlands University, along with 144 women members of the Couple to Couple League (CCL). The median waiting time to first menses was 12·8 months for the CCL mothers, an additional 7·8 months of amenorrhoea compared with the NM mothers.

shown in Fig. 2. For the NM mothers, the median waiting time to the first postpartum menstruation was 5·0 months with the first quartile menstruating by 2·9 months and the third quartile by 8·2 months postpartum. For the CCL mothers, the median wait was 12·8 months with the first quartile menstruating by 9·3 months and the third quartile by 18·2 months postpartum. The rate of menstrual cycle recovery for the NM participants was 2·6 times that of CCL participants. When the CCL mothers were divided into two groups depending on their employment status, it was found that women working away from their homes (in full-time or part-time employment) experienced a median of 8·2 months postpartum amenorrhoea, compared with a median of 13·9 months amenorrhoea for those whose livelihood allowed them to work at home. A survival model with the number of days per week of outside employment as the independent covariate yielded a hazard ratio of 1·252 ($p = 0{\cdot}003$). However, when the model was run for the NM participants, no significant effect of the work covariate was detected ($p = 0{\cdot}670$).

Tables 3 and 4 show the work covariate, other fixed covariates and binary covariates tested for the CCL and NM study populations, respectively. The timing of the first introduction of solid feeds was significant ($p = 0{\cdot}001$) for the NM group and ($p = 0{\cdot}013$) for the CCL group, and a strong predictor of increased risk of first menses for both groups. The age covariate also was statistically significant for both groups with a 7·7% ($p = 0{\cdot}026$) *increase* in the CCL participants' relative risk of menstrual

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**Table 3.** Single fixed covariate models: Couple to Couple League data set. Demographic and infant care statistics for 144 nursing mothers were used as covariates in a survival-time analysis of postpartum menstruation data contributed by participants recruited from the Couple to Couple League

| Covariate | Hazard ratio | Std error | $z$ | $p>\|z\|$ | 95% confidence interval | |
|---|---|---|---|---|---|---|
| Work (days/week)*** | 1·252 | 0·094 | 2·988 | 0·003 | 1·080 | 1·451 |
| Age (years)* | 1·077 | 0·036 | 2·231 | 0·026 | 1·009 | 1·149 |
| Bed (binary)* | 0·444 | 0·170 | −2·126 | 0·033 | 0·210 | 0·938 |
| Education (years) | 1·076 | 0·075 | 1·044 | 0·297 | 0·938 | 1·233 |
| Parity (number) | 1·083 | 0·085 | 1·009 | 0·313 | 0·928 | 1·263 |
| Ethnicity (binary) | 1·318 | 0·782 | 0·466 | 0·641 | 0·412 | 4·215 |
| Family income ($10 K) | 0·998 | 0·030 | −0·050 | 0·957 | 0·941 | 1·059 |

***Significant at the $p<0{\cdot}005$ level; *significant at the $p<0{\cdot}05$ level.

**Table 4.** Single fixed covariate models: New Mexico data set. Demographic and infant care statistics for 42 nursing mothers were used as covariates in a survival-time analysis of postpartum menstruation data contributed by participants recruited from northern New Mexico

| Covariate | Hazard ratio | Std error | $z$ | $p>\|z\|$ | 95% confidence interval | |
|---|---|---|---|---|---|---|
| Work (days/week) | 0·971 | 0·067 | −0·426 | 0·670 | 0·847 | 1·112 |
| Age (years)* | 0·924 | 0·034 | −2·147 | 0·032 | 0·860 | 0·993 |
| Bed (binary) | 0·690 | 0·348 | −0·736 | 0·462 | 0·257 | 1·855 |
| Parity (number) | 0·726 | 0·202 | −1·151 | 0·250 | 0·421 | 1·252 |
| Education (years) | 0·925 | 0·099 | −0·754 | 0·451 | 0·755 | 1·133 |
| Ethnicity (binary) | 1·958 | 0·810 | 1·623 | 0·105 | 0·870 | 4·405 |
| Family income ($10 K) | 0·822 | 0·122 | −1·322 | 0·186 | 0·615 | 1·099 |

*Significant at the $p<0{\cdot}05$ level.

cyclicity with each year of age. In contrast, the NM participants experienced a 7·6% ($p=0{\cdot}032$) *decrease* in the relative risk.

For the CCL participants, whether or not the babies shared a bed with the mother at night proved to be significant ($p=0{\cdot}033$). The relative risk of menstrual cycle recovery decreased by 55·6% if the mothers reported that they allowed their baby in bed with them at night. No comparable effect was detected for the NM participants ($p=0{\cdot}462$). The effect of the participants' ethnicity was tested by setting a binary variable equal to unity for women of Hispanic heritage (zero, otherwise). No relationship to the timing of postpartum menstrual activity was detected in either group for ethnicity, nor was there any effect due to their level of education, parity or annual family income.

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**Table 5.** Single time-varying covariate model: New Mexico data set. Four measures of breast-feeding behaviour and the introduction of solid feeds for 42 nursing mothers were used as time-varying covariates in a survival-time analysis of postpartum menstruation data contributed by participants residing in north-eastern New Mexico

| Covariate | Hazard ratio | Std error | $z$ | $p>\|z\|$ | 95% confidence interval | |
|---|---|---|---|---|---|---|
| Length (min) | 0·973 | 0·028 | −0·960 | 0·337 | 0·920 | 1·029 |
| Frequency (*n*/day) | 0·921 | 0·056 | −1·365 | 0·172 | 0·818 | 1·037 |
| Spacing (h)*** | 1·133 | 0·042 | 3·353 | 0·001 | 1·053 | 1·219 |
| Duration (h) | 0·700 | 0·160 | −1·556 | 0·120 | 0·447 | 1·097 |
| Solid feeds (binary)*** | 14·610 | 11·788 | 3·323 | 0·001 | 3·005 | 71·034 |

***Significant at the $p<0{\cdot}005$ level.

The time-varying covariates that were tested for their possible influence on the resumption of ovulatory activity after childbirth are presented in Fig. 3. This is a descriptive representation in which the population medians for the various statistical measures of breast-feeding performance are plotted for the New Mexico and Couple to Couple League data sets. Because these are medians, variability is apparent as the sample size falls when and as menstruation (response) and censoring (withdrawal) occurs. Beginning with about fourteen suckling sessions per day, the participants in the CCL study maintained their suckling frequency above five sessions per day throughout the length of observation that continued until censoring or first menses. The frequency for the NM group, in contrast, began at nearly twelve sessions per day and fell quickly to five sessions per day by the tenth month postpartum. A similar situation can be observed for the total time each day that the women participating in the study suckled their babies, starting at nearly 3 h per day for both groups near the time of birth. Then, a more rapid decline in the NM population is seen, as compared with the CCL sample. Also, as might be expected, the average spacing between suckling sessions for the NM group increased at nearly twice the rate as that observed for the CCL group of breast-feeding mothers. On the other hand, the median length of an individual session of breast-feeding remained constant at 10 min per session for both groups of mothers. Median session length remained relatively constant throughout lactational amenorrhoea for both study populations.

*Single time-varying covariate models*

The Cox survival-time single-covariate model of the NM data set revealed that the most significant predictors of the postpartum resumption of menstrual activity were the average spacing of suckling sessions ($p=0{\cdot}001$) and the introduction of solid feeds ($p=0{\cdot}001$). No evidence was found that median session length was associated with the rate of return to menstruation ($p=0{\cdot}337$). Likewise, no two-covariate model showed any improvement over the one-covariate models. Also, there was no evidence of varying hazard ratios with time. Table 5 shows the single-covariate model for the NM sample.

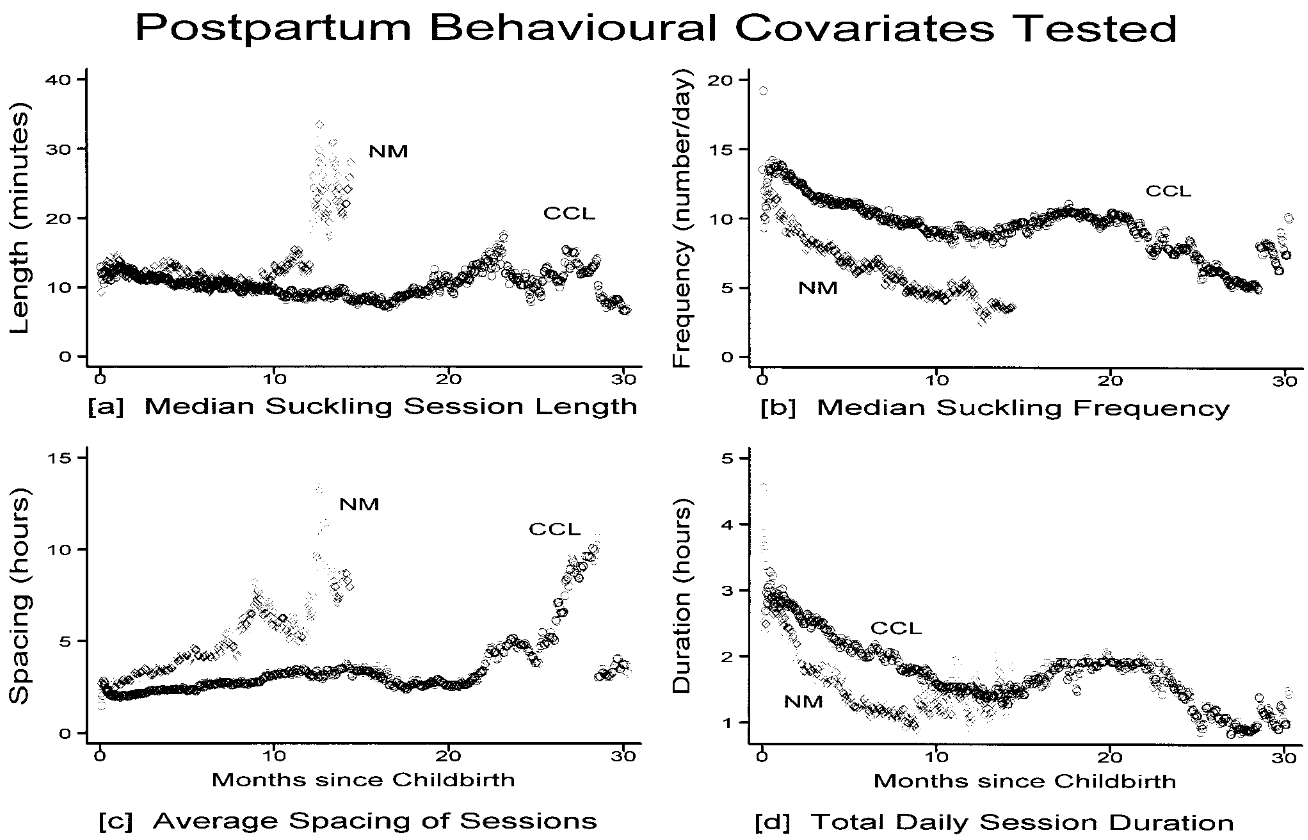


**Fig. 3.** Potential behavioural covariates related to the timing of the postpartum resumption of menstrual cycles are plotted for 42 New Mexico breast-feeding women (NM, open diamonds) and for 144 Couple to Couple League mothers (CCL, open circles). Population medians of four statistical measures of breast-feeding performance are shown: (a) median session length, (b) suckling session frequency, (c) average spacing of suckling sessions, and (d) total daily duration of breast-feeding sessions.

**Table 6.** Single time-varying covariate model: Couple to Couple League data set. Four measures of breast-feeding behaviour, mother-and-baby shared sleep and the introduction of solid feeds for 144 nursing mothers were used as time-varying covariates in a survival-time analysis of postpartum menstruation data contributed by participants recruited from the Couple to Couple League

| Covariate | Hazard ratio | Std error | $z$ | $p>\|z\|$ | 95% confidence interval | |
|---|---|---|---|---|---|---|
| Length (min) | 1·003 | 0·021 | 0·145 | 0·885 | 0·963 | 1·045 |
| Frequency (*n*/day)**** | 0·864 | 0·030 | −4·198 | 0·000 | 0·807 | 0·925 |
| Spacing (h)**** | 1·139 | 0·029 | 5·133 | 0·000 | 1·084 | 1·198 |
| Duration (h)** | 0·712 | 0·089 | −2·719 | 0·007 | 0·557 | 0·910 |
| Sleep (binary)**** | 0·419 | 0·101 | −3·608 | 0·000 | 0·262 | 0·672 |
| Solid feeds (binary)* | 5·529 | 3·798 | 2·489 | 0·013 | 1·439 | 21·252 |

*Significant at the $p<0·05$ level; **significant at the $p<0·01$ level; ****significant at the $p<0·001$ level.

For the CCL data set, hazard ratios consistent with the NM data set were found, with statistically significant relationships between each measure of breast-feeding performance and the return of ovulatory activity, except suckling session length ($p=0·885$). The most significant predictors of the postpartum resumption of menstrual activity were the average spacing of suckling sessions ($p=0·000$), the daily suckling session frequency ($p=0·000$) and the total daily duration of suckling sessions ($p=0·007$). Other significant behavioural covariates were mother-and-baby shared sleep ($p=0·000$) and the introduction of solid feeds ($p=0·013$). Again, no two-covariate model showed any improvement over the one-covariate models. Table 6 shows the single-covariate model for the CCL sample.

### *Multiple time-varying covariate models*

Hazard ratios for the NM and CCL studies are very similar. Formal tests for interaction showed no evidence of different hazard ratios at the two sites ($p=0·932$). However, the CCL subpopulation was less than half as likely to restart menstruation for each day of follow-up as the NM study population. As final best models, Table 7 shows the joint effect of study and spacing (Model 1) and the effect of spacing, treating ‘study’ as a stratifying variable (Model 2). Adding the binary variable ‘solid feeds’ to the model shows its effect to be significant and independent of the effects of suckling behaviour (Model 3). Finally, adding the fixed bed covariate (whether or not the baby ever slept with the mother) shows that independent effects may be attributable to the spacing of suckling sessions, the introduction of solid feeds and whether or not the mother and baby shared sleep (bed) in the night (Model 4).

In summary, pooling of the NM and CCL data sets revealed a daily hazard ratio (HR) for resuming menses of HR $=1·140$ given each hour of increase in the average spacing of suckling sessions. When study was treated as a stratifying factor rather than a dummy variable, the estimated pooled hazard ratio was HR $=1·137$. These values

**Table 7.** Multiple time-varying covariate models. Joint effect of study (NM participants vs CCL participants), the spacing of individual suckling sessions and the introduction of solid feed on the daily hazard of resuming menstruation for a total of 187 nursing mothers

| Covariate | Hazard ratio | Std error | $z$ | $p>\|z\|$ | 95% confidence interval | |
|---|---|---|---|---|---|---|
| Model 1 (study as a dummy variable) | | | | | | |
| Study (binary)**** | 0·246 | 0·061 | −5·680 | 0·000 | 0·152 | 0·399 |
| Spacing (h)**** | 1·140 | 0·023 | 6·419 | 0·000 | 1·095 | 1·186 |
| Model 2 (stratified on study) | | | | | | |
| Spacing (h)**** | 1·137 | 0·024 | 6·139 | 0·000 | 1·092 | 1·185 |
| Model 3 (stratified on study) | | | | | | |
| Spacing (h)**** | 1·127 | 0·027 | 4·919 | 0·000 | 1·075 | 1·182 |
| Solid feeds (binary)**** | 7·925 | 4·413 | 3·717 | 0·000 | 2·660 | 23·607 |
| Model 4 (stratified on study) | | | | | | |
| Spacing (h)**** | 1·127 | 0·030 | 4·490 | 0·000 | 1·070 | 1·187 |
| Solid feeds (binary)*** | 7·140 | 4·762 | 2·947 | 0·003 | 1·932 | 26·391 |
| Bed (binary)* | 0·492 | 0·172 | −2·046 | 0·041 | 0·239 | 0·970 |

*Significant at the $p<0{\cdot}05$ level; ***significant at the $p<0{\cdot}005$ level; ****significant at the $p<0{\cdot}001$ level.

were close to those found when the studies are pooled individually ($HR_{CCL}=1{\cdot}139$ and $HR_{NM}=1{\cdot}133$).

Further elaborations of the differences between suckling behaviours exhibited by both the NM and CCL study participants are possible when their respective data sets are viewed through time-windows. For this analysis, each 24-h day was divided into three windows: morning (0.00–08.00 h), daytime (08.00–16.00 h) and evening (16.00–24.00 h). These three equal, but arbitrary, windows were chosen to correspond roughly with sleeping, working and leisure times. Resulting single-covariate models for each of the three time-windows are presented in the upper portion of Table 8 for the NM data set and in the upper portion of Table 9 for the CCL data set. The hazard ratio for the NM women resuming postpartum menstrual cycles was 4·9% greater for each hour of suckling session spacing in the evening hours compared with their overall 24-h HR for session spacing. The CCL mothers also showed time-of-day variations in their HR for suckling session spacing. However, the HR increase was only 0·1% in the evening hours, but with a 10·4% HR increase in the daytime hours. In contrast, the NM mothers showed only a 1·1% increase in their daytime hazard ratio for suckling session spacing, compared with their overall 24-h HR for session spacing. During the morning hours, each group of mothers showed no more than 1·2% comparable decrease in their HR for session spacing.

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**Table 8.** Time-windowed New Mexico data set. Spacing covariate for 42 nursing mothers in a survival-time analysis of postpartum menstruation data contributed by participants residing in north-eastern New Mexico. Each 24-h day was divided into three equal intervals for these single- and triple-covariate models

| Spacing covariate | Hazard ratio | Std error | $z$ | $p > \|z\|$ | 95% confidence interval | |
|---|---|---|---|---|---|---|
| Single time-varying covariate models | | | | | | |
| Morning (00·00–08·00 h)* | 1·121 | 0·062 | 2·054 | 0·040 | 1·005 | 1·250 |
| Daytime (08·00–16·00 h)* | 1·144 | 0·066 | 2·340 | 0·019 | 1·022 | 1·280 |
| Evening (16·00–24·00 h)* | 1·182 | 0·081 | 2·436 | 0·015 | 1·033 | 1·352 |
| Multiple time-varying covariate model | | | | | | |
| Morning (00·00–08·00 h) | 1·050 | 0·074 | 0·687 | 0·492 | 0·913 | 1·206 |
| Daytime (08·00–16·00 h) | 1·059 | 0·091 | 0·668 | 0·504 | 0·895 | 1·253 |
| Evening (16·00–24·00 h) | 1·098 | 0·107 | 0·959 | 0·338 | 0·907 | 1·330 |

*Significant at the $p < 0·05$ level.

**Table 9.** Time-windowed Couple to Couple League data set. Spacing covariate for 144 nursing mothers in a survival-time analysis of postpartum menstruation data contributed by participants recruited from the Couple to Couple League. Each 24-h day was divided into three equal intervals for these single- and triple-covariate models

| Spacing covariate | Hazard ratio | Std error | $z$ | $p > \|z\|$ | 95% confidence interval | |
|---|---|---|---|---|---|---|
| Single time-varying covariate models | | | | | | |
| Morning (00·00–08·00 h)**** | 1·129 | 0·037 | 3·735 | 0·000 | 1·060 | 1·204 |
| Daytime (08·00–16·00 h)**** | 1·243 | 0·044 | 6·203 | 0·000 | 1·159 | 1·333 |
| Evening (16·00–24·00 h)*** | 1·140 | 0·046 | 3·270 | 0·001 | 1·054 | 1·233 |
| Multiple time-varying covariate model | | | | | | |
| Morning (00·00–08·00 h) | 1·033 | 0·044 | 0·778 | 0·437 | 0·951 | 1·123 |
| Daytime (08·00–16·00 h)**** | 1·217 | 0·059 | 4·062 | 0·000 | 1·107 | 1·337 |
| Evening (16·00–24·00 h) | 1·005 | 0·052 | 0·087 | 0·929 | 0·907 | 1·113 |

***Significant at the $p < 0·005$ level; ****significant at the $p < 0·001$ level.

A triple-covariate Cox model (see the lower portion of Table 8) with windowed spacing data supplied by the NM mothers showed no statistically significant hazard ratios for any of the suckling session spacing time-windows. In contrast, a

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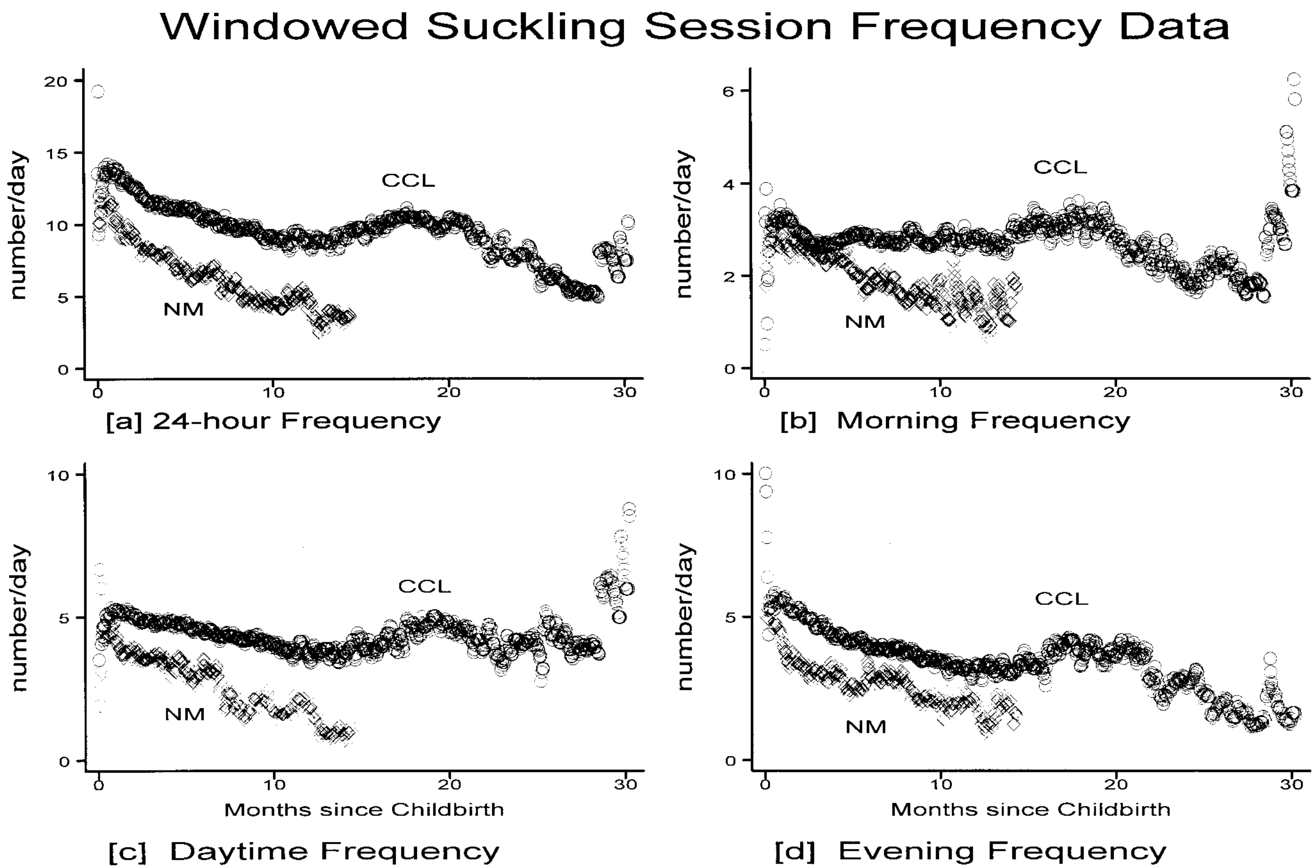


**Fig. 4.** Windowed suckling session frequency behavioural covariate plotted for 42 New Mexico breast-feeding women (NM, open diamonds) and for 144 Couple to Couple League mothers (CCL, open circles). Population medians for both groups: (a) 24-h frequency, (b) morning frequency, (c) daytime frequency, and (d) evening suckling session frequency.

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triple-covariate model (Table 9, lower) using the CCL mothers' windowed spacing data showed a highly significant ($p = 0{\cdot}000$) hazard ratio for suckling session spacing during the daytime hours (08.00–16.00 h).

Population medians of suckling session frequency may be seen in Fig. 4 for the morning, daytime and evening time-windows. Here, it is interesting that the frequency of morning suckling sessions (midnight to eight o'clock) remained constant at three sessions per morning for CCL mothers, while the NM mothers fell off from an initial frequency of about three sessions per morning to about one per morning at 12 months past childbirth. Also evident in Fig. 4 is a divergence in daytime suckling session frequency between the two study groups. The CCL and NM mothers have initially a nearly 5:5 ratio of daytime suckling sessions, one that increases to a 4:2 ratio by 10 months postpartum.

## Discussion

### *Event Recorder technology*

Participant recall of suckling activity is notoriously unreliable (for example, see Vitzthum, 1994b). Reasoning that concurrent observations of suckling activity were needed, the authors had previously developed a set of daytime and night-time nursing charts which required the participant to mark with a pencil the beginning and duration of suckling events. Participants' nursing charts then were digitally scanned to capture data on the times at which suckling bouts started and stopped (Taylor, 1989). This approach required that the participant first determine the current time before marking her chart, resulting in an estimated accuracy of $\pm 5$ min and a resolution of 5 min. The method was similar to that used in a comparative study of breast-feeding mothers in Baltimore and in Manila (Gray *et al.*, 1990) where participants kept a daily diary sheet.

Short of developing an intra-oral pressure transducer and data telemetry system, one is faced with the task of documenting suckling events that may persist for a few seconds or nearly an hour. The suckling events can occur almost anywhere and at any time of the day. The most difficult events to record are those that take place at night during times of shared sleep when neither the mother nor the baby may be fully awake during suckling. In an attempt to improve the quality of suckling data, the Event Recorder programme was developed (Taylor *et al.*, 1995). The internal clock of the calculator is set when the programme is downloaded, thus making it possible to time suckling events to the nearest second. An audible tone feature may be easily activated by the participant making it possible for her to enter data at night without lights. The Event Recorder programme gives participants the option of recording any missed bouts, supplemental feeding and menses data. Use of the Event Recorder has provided an unprecedented look at suckling behaviour for relatively large groups of participants. For instance, day-by-day trends in key suckling statistics (frequency, spacing, length and duration) can be observed. In addition, time-of-day effects can be seen by setting arbitrary windows of observation for each day. The unique Event Recorder programme, and an easy-to-use Windows95 programme for compiling, viewing and processing Event Recorder data files (including individual or ensemble events and exponential smoothing), are freely available to interested researchers via an Internet server at Universal Resource Locator (URL): http://vyne.nmhu.edu/mbrs/.

*Suckling session frequency and suckling session spacing*

The daily suckling session frequency and the average spacing of suckling sessions are inversely related. According to the single-covariate model of Table 5 (NM data), there is a greater degree of fit for the spacing covariate ($p = 0{\cdot}001$) compared with the frequency covariate ($p = 0{\cdot}172$). This suggests that the importance of suckling *per se* in the maintenance of postpartum amenorrhoea increases as the number of suckling sessions per day is reduced. That is, when the daily suckling session frequency is relatively high, say above six per day, the relative importance of a unit fall in frequency has a lesser impact on the rate of resumption of menses than when the frequency is already at a lower level. As an illustrative example, a reduction in frequency from twelve suckling sessions per day to six is equivalent to an increase in average spacing of just 2 h. The model, for example, of Table 6 for spacing predicts that the hazard ratio associated with this change would be $HR = exp(2ln1{\cdot}139) = 1{\cdot}297$. It also predicts that a reduction in session frequency from eight per day to two, an identical incremental reduction in frequency with an increase in average spacing of 9 h, is associated with a hazards ratio of 3·226. That is, the relative risk of resuming ovulatory activity would be more than three times greater for the latter reduction in suckling session frequency.

The use of the spacing covariate in a proportional hazards model of the postpartum recovery of menstrual cycles is new, although the closely related *interbout interval* has been long recognized as a possible key variable in lactation infertility (Konner & Worthman, 1980; Wood *et al.*, 1985). However, suckling pattern is often expressed in terms of the frequency covariate (Taylor, 1989; Taylor *et al.*, 1991). The Baltimore–Manila study (Gray *et al.*, 1990, Table II) showed a HR of 0·861 ($p = 0{\cdot}38$, $n = 101$) for the number of breast-feeds per day. The authors' pooled data, stratified by study, gave an almost identical result of HR = 0·877 ($p = 0{\cdot}000$, $n = 186$).

*Differences and similarities between the two populations*

Interestingly, the CCL–NM difference is not explained by the measured covariates. The two groups of breast-feeding mothers seem to represent two substantially different populations as to their breast-feeding behaviour. It is likely that the regional women (NM) began weaning earlier than the women in the ecological breast-feeding sample (CCL). The mean time for the introduction of solid feeds for the NM mothers was 4·5 months, while the comparable time that mothers of the CCL sample introduced solids was 6·1 months. This result is consistent with a report from investigators at the University of California Davis (Heinig *et al.*, 1994) who found markedly shorter postpartum amenorrhoea for their formula-feeding and supplemented breast-feeding group (mean of 2·7 months for 42 mothers, including nine who did not breast-fed at all) as compared with their breast-feeding group (mean of 8·9 months for 61 mothers).

The probability distribution of the time to first menses for the two study populations was estimated by computing the differences in the Kaplan–Meier survival estimates at every second month after childbirth and plotting a smooth curve through those points (see Fig. 5). Because of the differences in both the menstrual resumption rate and suckling frequency for the two groups in the face of almost identical hazards ratios for both the frequency and spacing covariates, the mean suckling frequency of all study participants was examined in their first three postpartum months.

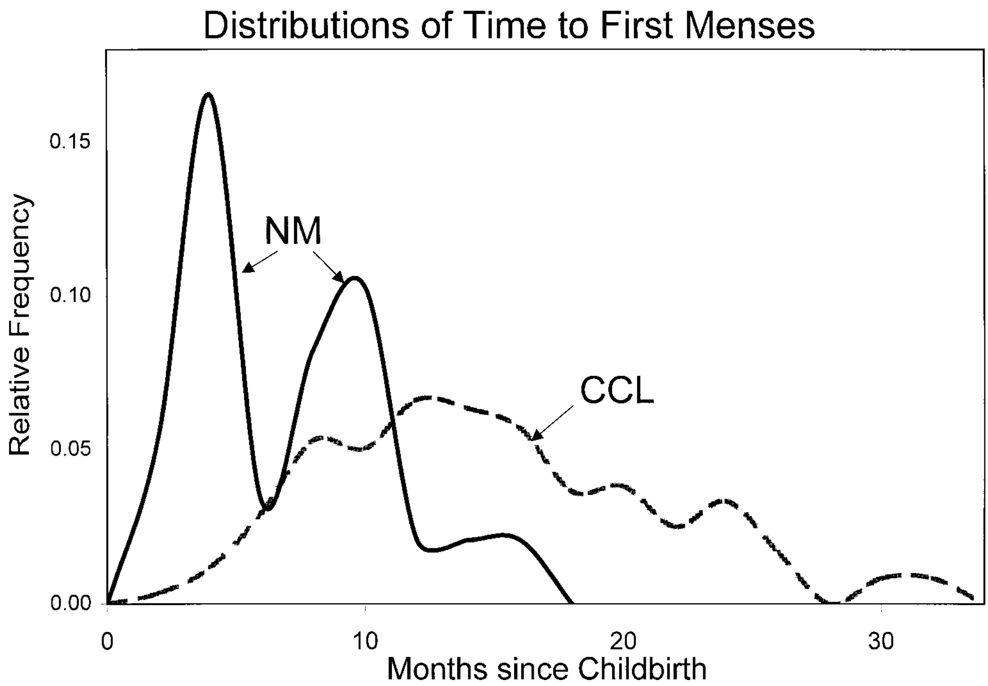


**Fig. 5.** Probability distributions of first postpartum menstruation from differences in bimonthly Kaplan–Meier survival estimates for 42 New Mexico breast-feeding women (NM, solid line) and for 144 Couple to Couple League mothers (CCL, dashed line). The bimonthly estimates were then fitted with a smooth curve.

Approximately one-half (52·4%) of the NM study participants suckled at an average frequency of nine or more sessions per day in the first 3 months, while most (83·5%) of the CCL group suckled for an average frequency of at least nine sessions per day.

For pooled NM and CCL participants, the median time of first menses for mothers with a low suckling frequency early-on ($<9$ suckling sessions per day in the first 3 months) was 8·0 months, while the median length of postpartum amenorrhoea for the high-frequency group ($\geq 9$ suckling sessions per day) was 12·2 months. Either the effects of the early suckling pattern are persistent or the early pattern foreshadows suckling behaviour to follow, since a proportional hazards model using the median value of the spacing covariate in the first 3 months as a *fixed* covariate revealed a hazard ratio of 1·168 ($p = 0{\cdot}002$) when stratified by study. These results are quite similar to the observations of 32 women in Boston, half of whom were recruited from La Leche League (Elias *et al.*, 1986). There, suckling frequency was assessed at eight specified times in the first 24 months after childbirth, with 'frequent nursing' associated with an additional 5·1 months amenorrhoea, compared with the 'infrequent nursing group'.

Suckling session length for both the NM and CCL study populations showed little variation during postpartum amenorrhoea. Intriguingly, it was found that women who experienced amenorrhoea past 17 months had suckled for an average median of 6·8 min per session from the third through the sixth month after childbirth. In contrast, the average population median for the CCL sample as a whole was much higher, at

10·6 min per session (the corresponding NM session length was 11·8 min). For the Gainj of highland New Guinea (Wood *et al.*, 1985), breast-feeding mothers were observed to suckle for episode durations of only 3·3 min. Between 3 and 6 months postpartum, the Gainj average suckling episode spacing was about 0·47 h, compared with an average suckling session spacing of 1·94 h for the CCL mothers with extended amenorrhoea and 2·35 h for the CCL sample as a whole (the corresponding NM session spacing was 3·82 h). With the caution that here an attempt is being made to compare suckling episodes with suckling sessions (episodes separated by less than 60 s were joined into one session), the suggested differences may help to explain why some mothers in recently contacted populations experience a more extended amenorrhoea, as compared with the present study participants.

The time-windowing data presented in Fig. 4 and Tables 7 and 8 suggest two remarkable features concerning differences in the style of breast-feeding behaviour exhibited by the two study groups. The first feature concerns night-time breast-feeds. The fact that the CCL group could maintain the frequency of suckling sessions between midnight and eight o’clock in the morning at a constant level, may be the result of sleeping accommodations that encourage sleep-time suckling activity. On the other hand, the decline in suckling frequency during this time interval for the NM population may indicate success in ‘getting the baby to sleep through the night’ (apparently, a current US cultural value) and less of a desire for sleeping arrangements to accommodate sleep-time sucklings. The decline in night-time suckling frequency may be due in part to diminished support of breast-feeding by the NM male partners as contrasted with the CCL husbands.

The second feature suggested by the windowed suckling data is the relative importance of daytime sucklings for the maintenance of postpartum amenorrhoea among the CCL mothers, a phenomenon not seen in the NM sample. As a group, the CCL mothers stayed with their babies (90·3%, according to Table 2) during their postpartum amenorrhoea, allowing them to suckle freely throughout the day. A relatively large proportion of the NM mothers returned to work or school (28·6%), forcing them to devote their evenings more for the suckling needs of their babies than the CCL mothers. Results of the analysis implicate the mother’s separation from her baby for the exigencies of out-of-household employment in a drastic shortening of the postpartum amenorrhoeic interval. It is estimated that this effect accounts for about one-third of the difference in the two populations.

Women in traditional breast-feeding cultures apply a variety of strategies conducive to successful lactation while responding to complex demands of subsistence workloads (Panter-Brick, 1989). While growing up, girls learn the social cues that facilitate the integration of suckling with a myriad of daily activities. So far in technologically developed cultures, girls are being deprived of the patterning afforded elsewhere. Business and institutions undermine the intentions of breast-feeding women by excluding their infants and giving them no alternative but separative childcare. The result is an ecological imbalance, one that will require strong advocacy and legal protections to rectify.

## Conclusions

In this study, the New Mexican breast-feeding sample and the USA sample of Couple to Couple League mothers tended to be similar in their patterns of breast-feeding performance during the first few weeks after childbirth. During the puerperium, mothers in both groups were at home with their babies. However, long-term breast-feeding measures for the two groups diverged markedly. Some mothers returned to their prenatal activities with the help of the extended family, and others resumed the duties of taking care of more than one child. Some women's social activities centred around home and friends in like situations (other mothers who were also nursing babies), and others resumed tasks in the workplace outside the home, necessitating leaving the baby in some kind of childcare arrangement.

Decreased suckling session frequency and decreased total breast-feeding duration each day were found to signal a higher time-specific probability of recovering menstrual cyclicity. Simultaneously, the risk of escaping from postpartum amenorrhoea increased with increased average suckling session spacing. These observations lend credence to the claim that an intermittent pattern of short-frequent sessions is more effective for the continuance of postpartum amenorrhoea than a dosed pattern of scheduled long-interval sessions (Konner & Worthman, 1980).

Although both participant groups show a significant dependence on breast-feeding performance and on the delay of solid feeds for the maintenance of postpartum amenorrhoea, other factors not accounted for in this study also may be involved. Putative covariates, candidates for further investigation, include the following: liquid supplementation, use of pacifiers, schedules, infant artifacts such as seats and swings, babysitters and other patterns of separation between mother and baby. Stated positively, when babies (1) sleep with the mother, (2) are held close to the mother's body, and (3) accompany her everywhere, the resulting easy access to the breast may be a causative factor in the ecology of breast-feeding's contraceptive effect.

Further studies, currently underway, will allow the extension of this investigation to a population of semi-rural women residing in equatorial Africa. Other experience in that region suggests a high acceptance rate of breast-feeding and natural family planning (Ravera *et al*., 1995). Beyond the collection of menstrual histories from study participants in the USA and Cameroon, the authors are also collecting dry urine samples for ovarian hormone assay according to a technique developed previously (Shideler *et al*., 1995). Focused ethnographic studies are needed to clarify the circumstances, beliefs and attitudes that form the milieu in which the American and African study participants attempt to breast-feed with varying degrees of success.

The unique time-series suckling data allowed an examination of time-of-day effects with arbitrary windows of observation set throughout the day. The results of the windowed survival analysis give a new and detailed view of the mother–baby equation in human reproductive ecology. For a society that encourages mother–baby inseparability, its ecological role is highlighted: one that tends to avoid community population pressures while at the same time offering important health benefits for the mother and her developing child.

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