Feeding methods, sleep arrangement, and infant sleep patterns: a Chinese population-based study

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Original article

Background: **Findings from prior research into the effect of feeding methods on infant sleep are inconsistent. The objectives of this study were to examine infants' sleep patterns by feeding methods and sleep arrangement from birth to eight months old.**

Methods: **This longitudinal cohort study enrolled 524 pregnant women at 34-41 weeks of gestation and their infants after delivery in 2006 and followed up until eight months postpartum. The study subjects were recruited from nine women and children hospitals in nine cities in China (Beijing, Chongqing, Wuhan, Changsha, Nanning, Xiamen, Xi'an, Jinan, and Hailin). Participating infants were followed up weekly during the first month and monthly from the second to the eighth month after birth. Twenty-four hour sleep diaries recording infants' sleeping and feeding methods were administered based on caregiver's self-report. Multivariable mixed growth curve models were fitted to estimate the effects of feeding methods and sleep arrangement on infants' sleep patterns over time, controlling for maternal and paternal age, maternal and paternal education level, household income, supplementation of complementary food, and infant birth weight and length.**

Results: **Exclusively formula fed infants had the greatest sleep percentage/24 h, followed by exclusively breast milk fed infants and partially breast milk fed infants (P<0.01). Night waking followed a similar pattern. However, the differences in sleep percentage and night waking frequency between exclusively formula and exclusively breast milk fed infants weakened over time as infants developed. In addition, compared to infants with bed-sharing sleep arrangement, those with room sharing sleep arrangement had greater daytime and 24-hour infant sleep percentage, whereas those with sleeping alone sleep arrangement had greater nighttime sleep percentage.**

Conclusions: **Our data based on caregiver's self-report suggested that partial breastfeeding and bed-sharing may be associated with less sleep in infants. Health care professionals need to work with parents of newborns to develop coping strategies that will help prevent early weaning of breastfeeding.**

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Key words: **breast feeding;**
feeding method;
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Introduction

Infant sleep is a topic of great concern for many parents. Because the circadian rhythm is not fully established at birth, a newborn infant has different circadian rhythms compared with an older child.[1] The sleep pattern of a newborn is irregular, with an average sleep period ranging from 2.5 to 4 hours.[1] Although the development of infants' sleep/wake patterns depends largely on their own physiologic characteristics, external factors are also closely related to infant sleep rhythms, including feeding methods and frequency, sleep arrangement, and transitional objects needs (i.e., sucking the nipple, cuddling toy, rocking, holding in the arm) at bedtime or after a night waking.[2-7]

A number of studies[8-12] have documented an association between feeding methods and infant

sleep patterns. However, findings from research into the relationship between feeding methods and infant sleep were inconsistent. Some studies[8,10] found no significant differences in sleep patterns between breast- and formula-fed infants, while other studies observed that breastfeeding newborns slept less, woke more frequently, or stayed awake longer compared to formula fed infants.[9,12] Cohen et al[11] and Ramamurthy et al[12] found breastfed infants had longer durations of daytime or nighttime sleep as well as more total sleep durations than formula fed infants. In addition to lack of consistent findings, previous studies were also limited by cross-sectional study design and small sample size.

Research has suggested that either "parental presence until sleep onset" or "excessive (i.e., greater than the sample mean) active physical comforting (e.g., cuddling in arms)" combined with reduced "encouragement of infant's autonomy (e.g., leaving to cry)" over time was associated with parent perceived infant sleeping problems.[13] Further studies[14,15] indicated that bed-sharing (i.e., sleeping in the same bed with an adult) was associated with more frequent night wakings in infants, when compared with infants with sleeping alone sleep arrangements. However, these studies have not examined the influence of sleeping arrangements on the changes in infants' sleep patterns as they develop over time.[16-18] It has been shown that infants who habitually relied on transitional objects to fall asleep were associated with delayed development of the ability to fall asleep on their own. This, in turn, can result in difficulty in falling asleep at bedtime or in more frequent night wakings.[5,19] However, little is known about the types of transitional objects infants need to go back to sleep by feeding methods.

Parents' perceptions of infant sleep problems, including difficulty in falling asleep and multiple and prolonged night wakings, often cause family distress and are among the most common complaints to pediatricians and other child-care professionals.[20] Having knowledge of normative sleep patterns in infancy can help reassure parents with newborns and ease their anxiety. It can also facilitate physicians and other child-care professionals working on sleep complaints with parents of newborns to accurately identify sleep problems and to provide early preventive measures, if necessary, to maximize child development.[2] However, more research is needed to determine the associations between feeding methods and sleep arrangements and infants' sleep patterns and behaviors. To address these gaps in the literature, this large population-based longitudinal study examined the association between feeding methods, sleep arrangements, infants' sleep patterns, and sleep behaviors from birth to eight months of age in a Chinese population.

Methods

Sample

This longitudinal cohort study enrolled urban-dwelling pregnant women at 35-41 weeks of gestation from January to May in 2006 and followed up with participants until eight months postpartum. This study was approved by the Institutional Review Board at the National Center for Women and Children's Health of Chinese Center for Disease Control and Prevention. All the enrolled pregnant women and their husbands were informed of the study process and signed the consent forms. Multistage sampling was used for sample selection with region (i.e., North, Central, and South regions) as the primary sampling unit. At the second stage of sampling, provinces and municipalities were selected from the primary sampling units proportionate to the population size. A total of seven provinces and two municipalities were selected into the study from the north (one municipality and three provinces), central (two provinces), and south (one municipality and two provinces) regions of China. The capital city of each of the selected provinces was designated as the study site (i.e., Beijing, Chongqing, Wuhan, Changsha, Nanning, Xiamen, Xi'an, Jinan, Hailin), except for two cities in Hailin and Xiamen. At the third stage of sampling, nine women and children hospitals were randomly selected from the aforementioned study sites. And the study subjects were randomly recruited from these nine women and children hospitals by direct mail, phone, or outpatient service. The majority of the deliveries in urban areas in China are made at the women and children hospitals. All researchers received standardized training of the research protocol. Regular quality assurance and control were conducted at least once every quarter. Training workshops were held to reinforce the standardized assessment of sleep parameters, feeding methods, and sleep arrangement to ensure compliance in the research protocol in each study site.

Maternal inclusion criteria were 35-41 weeks of gestation, 20-35 years of maternal age, and receiving prenatal care or well-baby visits at the participating women and children hospitals. Exclusion criteria were a family history of mental illness (e.g., depression, psychosis), as well as maternal complications including pregnancy-induced hypertension, gestational diabetes, and anemia. Eligibility criteria for infants included gestational age between 37 and 42 weeks and birth weight between 2500 and 4000 g, without birth trauma, apnea, serious birth defects, congenital anomalies, infectious diseases, central nervous system disorders, or acute cardio-pulmonary conditions. This resulted in a sample of 524 infants from 720 mother-infant pairs who

were consented. Totally 196 subjects did not participate in the study after the initial consent due to relocation (124 cases), illness (27 cases), and withdrawal (45 cases). The researchers devoted great efforts to improve retention by providing a follow-up calendar, frequent contacts with subjects by phone and home visits, and occasional social events for parents. The sensitivity analysis was conducted to compare sample characteristics between those who consented but did not participate in the study with the final study sample. There was no statistical difference between the two groups in child sex, birth weight and length, gestational age, paternal age, maternal and paternal education level, or household income. However, mothers who initially consented but did not participate in the study were younger (by 0.86 year old, P=0.023) than those who consented and participated in the study.

Infant sleep patterns, behaviors, and feeding methods

Infant sleep patterns and behaviors were based on maternal self-report. A sleep diary was used to monitor the infants' 24-hour sleep/wake patterns and feeding methods. This study used a modified version of the Barnard and Eyres Sleep Activity Record.[21] We modified the Barnard and Eyres Sleep Activity Record by adding the assessment of the feeding method to the instrument. Barr and colleagues[22] observed a correlation (r=0.85) between mothers' sleep-wake diaries of their infants and audiotapes of fuss and cry behavior of their infants. The 24-hour day was divided into 96 15-minute blocks of time, and the mothers were instructed to record each sleep time period or epoch of their infants by describing a line between the two points closest to the start and the end time. Parents also marked feeding time with a letter "B" or "F" on the diary to indicate breastfeeding or formula feeding. Enrolled families were followed up for infant sleep and feeding method measurements starting 24 hours after delivery, weekly during the first month, and monthly from the second to the eighth month after delivery. At least two persons from the enrolled family received training on how to complete the infant sleep diary. The sleep diary was recorded continuously for a period of 72 hours in every week for the first four weeks, followed by seven consecutive days' recording at each monthly assessment till eight months after birth.

Infant sleep assessment was supplemented with the "Sleep Behavior Questionnaire", adopted from the Sleep Evaluation Questionnaire.[23] It was completed by the mothers at the first, third, fifth, and eighth month well baby checkups to record the infants' sleep behaviors in the most recent month. Specific areas of inquiry included: 1) sleep arrangement; 2) sleep-onset assistance at bedtime (involving: eating, sucking pacifiers or other items, rocking or patting, light on, and others); 3) transitional objects needs as described above when babies woke during nighttime sleep. Information on labor and delivery was also abstracted from medical records for enrolled mothers.

Feeding methods and sleep arrangements were our exposures of interest. Feeding methods included exclusive breastfeeding (EB), partial breastfeeding (PB), and exclusive formula feeding (EF)[24] during the reporting period for each assessment interval. Feeding method was mainly determined by the type of milk fed as reported by the infant's caregiver. EB was defined as feeding infants only breast milk, and no other types of milk. If infants were exclusively fed breast milk in a bottle when enrolled mothers used a breast pump, it was considered exclusively breastfeeding. PB referred to infants fed by a combination of breast milk, formula milk, and animal milk during the reporting period for each assessment interval, and EF referred to infants fed by formula milk or animal milk, without breast milk. However, it is very rare for children aged younger than 2 years old to receive animal milk, according to the infants' feeding guidelines in China. Sleep arrangements included sleeping in the same bed with an adult (bed-sharing), sleeping in a separate crib in the same room with an adult (room-sharing), and sleeping in a separate room and crib (sleeping alone).

The outcomes of interest included infant daytime, nighttime, and 24-hour sleep percentage, number of naps, nocturnal longest sleep time, and frequency of night waking. Day and night were defined on a 12-hour block of time (8 a.m. to 8 p.m. and 8 p.m. to 8 a.m.). Infant naps were defined as the sleep intervals occurring between 8 a.m. and 8 p.m.

Statistical analysis

Descriptive analysis was conducted to characterize the study sample. The chi-square test was used to examine the relationship between feeding methods and sleep arrangements or transitional objects needed at bedtime or after a night waking. Data of this study were repeated measurement data. To accommodate the clustered structure of the data, the mixed model analysis of hierarchical linear modeling was used to estimate intra-individual time-based trajectories and test whether inter-individual differences in the parameters of these trajectories were a function of time-variant exposure of interests in each model.[25] Some enrolled women changed feeding methods or infant sleeping arrangements over time as infants aged. The mixed modeling approach takes into consideration the changes in feeding methods or sleep arrangements over time as the infant ages, as data from each assessment interval

were included in the mixed model.[25] Subjects with data from at least two assessment intervals were included in the analysis.

Two-level multilevel mixed models were fitted. The level 1 model included assessment intervals (infant age). Exposures of interest along with potential confounders were included as level 2 variables. A general form of the full hierarchical linear mixed model is as follows:

$$Y_{ij}=\beta_0+\beta_1 A_{1j}+\beta_2 age_j+\beta_3 (A_{1j}\times age_j)+X_{1j}+u_{0j}+e_{ij}$$

Y_{ij} refers to the sleep parameters value from infants' sleep diaries. A_{1j} refers to infants' feeding methods or sleep arrangements. $A_{1j}\times age_j$ represents the interaction of infants' age and exposure variables. A_{1j} includes potential confounders, which may be independently associated with the exposure and the infant sleep parameters. The potential confounders included parental age, parental education levels, family income, supplementation of complementary food, and infant birth weight and length. Complementary food includes cereals (rice, wheat, etc.), meat (pork, beef, sheep, poultry, etc.), animal liver, animal blood, eggs, fish and shrimp, soy products, fruit, and vegetables. u_{0j} represents the unobserved infants' factors that affect infants' sleep outcomes. All tests were two-tailed and $P<0.05$ was considered statistically significant. All analyses were based on unweighted data without adjusting for the probability sampling and conducted with SPSS software (Beijing Stats Data Mining Co. Ltd.).

Results

Feeding methods and sleep arrangements

Our study sample had similar proportions of male and female infants with a mean gestational age at enrollment of 39 weeks and a mean infant birth weight of 3391 g. The average maternal and paternal ages were 28.5 and 31.0, respectively (Table 1). The majority of parents had education levels of high school or greater. Approximately 46% of the family household income was over 3000 RMB (about US $480) per month. During the first eight months postpartum, more than half of the enrolled subjects chose EB over PB or EF, even though the prevalence of EB showed a steady decline after second month postpartum and the prevalence of EF increased steadily soon after delivery (Fig. 1, $P<0.001$). For sleep arrangement, the practice of bed-sharing became more prevalent over time and increased from 46% to 60% by eight months postpartum, whereas the percentage of sleeping alone sleep arrangement reduced from 21% to 7% over time

Table 1. Demographic characteristics of the study participants (n=524)

Demographics	Value
Male, %	50.2
Gestational age, mean (SD), wk	39.1 (1.3)
Birth weight, mean (SD), g	3391.8 (401.1)
Birth length, mean (SD), cm	50.4 (1.9)
Maternal age, mean (SD)	28.5 (3.3)
Paternal age, mean (SD)	31.0 (3.8)
Mother's attained education, %	
Junior high school and under	10.6
High school (technical secondary school)	28.7
Junior college	26.4
University and above	34.3
Father's attained education, %	
Junior high school and under	8.3
High school (technical secondary school)	24.7
Junior college	22.5
University and above	44.5
Household monthly income, %	
<1000 RMB	8.8
1000-2000 RMB	24.3
2001-3000 RMB	21.1
3001-5000 RMB	26.2
5001-8000 RMB	14.1
>8000 RMB	5.5

SD: standard deviation.

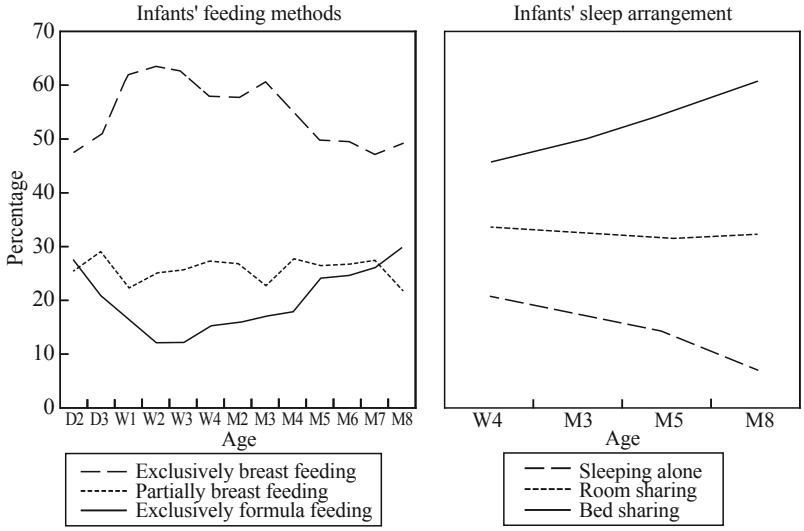

Fig. 1. Infants' feeding methods and sleep arrangement during the study period.

(Fig. 1). Meanwhile, the prevalence of room-sharing at eight months after delivery remained steady around 32% over the study period. In evaluating the association between feeding methods and sleep arrangements, no significant difference was found in the sleep arrangement by infants' feeding methods during the study period (data not shown).

Infant sleep-wake patterns by feeding methods

After controlling for parental ages, education levels, total household income, supplementation of complementary food, infant birth weight, and infant birth length, our multivariable mixed models estimated that the mean trajectory for each sleep parameter has a non-zero intercept and a non-zero slope (Tables 2 and 3).

Table 2. Multilevel mixed models of the effects of feeding methods on infants' sleep-wake patterns

Effects	Prediction of 24-hour sleep percentage		Prediction of daytime sleep percentage		Prediction of night waking frequency	
	β (SE)	*P* value	*β* (SE)	*P* value	*β* (SE)	*P* value
Fixed effects						
Intercept	85.14 (9.48)	<0.0001	97.00 (19.59)	<0.0001	1.73 (0.77)	0.0241
Rate of change in sleep patterns (slope)	-1.36 (0.16)	<0.0001	-4.16 (0.37)	<0.0001	-0.15 (0.01)	<0.0001
Feeding methods						
EB	-2.13 (0.64)	0.0009	-3.96 (1.52)	0.0093	0.11 (0.06)	0.0700
PB	-3.05 (0.68)	<0.0001	-6.20 (1.63)	0.0002	0.16 (0.07)	0.0177
EF	Reference		Reference		Reference	
Rate of change (slope)×feeding methods						
Rate of change×EB	0.44 (0.14)	0.0025	1.31 (0.35)	0.0002	-0.03 (0.01)	0.0444
Rate of change×PB	0.55 (0.17)	0.0009	0.89 (0.40)	0.0257	-0.03 (0.02)	0.1121
Rate of change×EF	Reference		Reference		Reference	
Complementary food*						
No	4.96 (0.77)	<0.0001	11.44 (1.79)	<0.0001	0.44 (0.07)	<0.0001
Yes	Reference		Reference		Reference	
Rate of change (slope)×complementary food						
Rate of change×no	-3.14 (0.22)	<0.0001	-4.68 (0.52)	<0.0001	-0.17 (0.02)	<0.0001
Rate of change×yes	Reference		Reference		Reference	
Maternal age	0.09 (0.13)	0.4619	0.33 (0.26)	0.1992	-0.01 (0.01)	0.3910
Paternal age	0.10 (0.11)	0.3524	-0.04 (0.22)	0.8616	0.01 (0.01)	0.3894
Mother's attained education	-0.63 (0.51)	0.2144	-1.81 (1.04)	0.0824	0.00 (0.04)	0.9765
Father's attained education	0.14 (0.51)	0.7840	0.27 (1.06)	0.8001	-0.02 (0.04)	0.5507
Household monthly income	0.03 (0.29)	0.9173	-0.64 (0.59)	0.2804	-0.01 (0.02)	0.5826
Infant birth weight	0.00 (0.00)	0.3278	0.00 (0.00)	0.2723	0.00 (0.00)	0.5875
Infant birth length	-0.58 (0.19)	0.0028	-0.76 (0.40)	0.0567	0.00 (0.02)	0.9935
Random effects (variance components)						
Residual (level 1)	68.75 (1.65)	<0.0001	408.48 (9.85)	<0.0001	0.66 (0.02)	<0.0001
Intercept (level 2)	38.25 (3.12)	<0.0001	146.09 (13.57)	<0.0001	0.22 (0.02)	<0.0001

EB: exclusively breast feeding; PB: partially breast feeding; EF: exclusively formula feeding; SE: standard error. *: a binary indicator that was assessed at 5 and 8 months of infant age based on maternal self-report.

Table 3. Multilevel trajectory models of the effects of sleep arrangements on infants' sleep-wake patterns

Effects	Prediction of 24-hour sleep percentage		Prediction of daytime sleep percentage		Prediction of nighttime sleep percentage	
	β (SE)	*P* value	β (SE)	*P* value	β (SE)	*P* value
Fixed effects						
Intercept	88.20 (9.44)	<0.0001	106.45 (19.80)	<0.0001	71.66 (14.20)	<0.0001
Rate of change in sleep patterns (slope)	-1.32 (0.08)	<0.0001	-4.44 (0.20)	<0.0001	1.78 (0.15)	<0.0001
Sleep arrangement						
Sleeping alone	1.33 (0.75)	0.0743	-0.96 (1.72)	0.5780	3.63 (1.31)	0.0056
Room sharing	2.33 (0.65)	0.0003	3.43 (1.49)	0.0213	1.39 (1.14)	0.2202
Bed sharing	Reference		Reference		Reference	
Rate of change×sleep arrangement						
Sleeping alone×rate of change	-0.61 (0.19)	0.0016	0.12 (0.45)	0.7830	-1.35 (0.35)	0.0001
Room sharing×rate of change	-0.44 (0.14)	0.0024	-0.83 (0.34)	0.0145	-0.06 (0.26)	0.8273
Bed sharing×rate of change	Reference		Reference		Reference	
Maternal age	0.08 (0.13)	0.5424	0.41 (0.27)	0.1340	-0.26 (0.19)	0.1820
Paternal age	0.14 (0.11)	0.1888	-0.07 (0.23)	0.7687	0.36 (0.16)	0.0278
Mother's attained education	-0.59 (0.52)	0.2512	-1.79 (1.08)	0.0964	0.62 (0.77)	0.4217
Father's attained education	0.14 (0.52)	0.7928	0.16 (1.10)	0.8840	0.10 (0.79)	0.8970
Household monthly income	-0.05 (0.30)	0.8692	-0.89 (0.62)	0.1558	0.78 (0.45)	0.0815
Infant birth weight	0.00 (0.00)	0.2952	0.00 (0.00)	0.2435	0.00 (0.00)	0.7959
Infant birth length	-0.67 (0.19)	0.0005	-0.91 (0.41)	0.0249	-0.47 (0.29)	0.1082
Random effects (variance components)						
Residual (level 1)	74.16 (1.85)	<0.0001	420.11 (10.48)	<0.0001	256.88 (6.42)	<0.0001
Intercept (level 2)	35.81 (3.11)	<0.0001	144.09 (13.83)	<0.0001	68.47 (7.24)	<0.0001

SE: standard error.

The variances around the mean intercept and slope were also significant (Tables 2 and 3), indicating that there is notable diversity in infants' individual trajectories of sleep patterns. In other words, there were differential effects of feeding methods and sleeping arrangements at the various time points. The slope was the rate of change in sleep patterns over time represented by infant age at each assessment interval.

Controlling for covariates, we observed a statistically significant association between feeding methods and infant daytime sleep percentage, 24-hour sleep percentage, and the frequency of night waking over time (Table 2), but not in nighttime sleep percentage, number of daytime naps, or maximum nocturnal sleep length (data not shown). On average, compared to EF infants, EB and PB infants were associated with lower 24-hour sleep percentage in the first eight months by 2.1% (equivalent of 30 minutes less per 24 hours, $P<0.01$) and 3.1% (equivalent of 45 minutes less per 24 hours, $P<0.01$), respectively (Table 2). Similarly, on average, EB and PB infants presented daytime sleep percentages lowered by 4.0% (equivalent of 58 minutes less, $P=0.01$) and 6.2% (equivalent of 89 minutes less, $P<0.01$) than EF infants, respectively (Table 2). In nocturnal waking, PB infants were associated slightly with more frequent night wakings on average compared with EF infants. The relationship between EB and daytime and 24-hour sleep percentage and night waking changed over time with a significant interaction with the rate of change ($P=0.03$, Table 2). The association between PB on 24-hour sleep percentage and nocturnal waking also varied over time with a statistically significant interaction with the rate of change and PB ($P<0.05$, Table 2). Specifically, the differences in sleep percentages and night waking between EF, EB, and PB decreased over time during the study period (Fig. 2).

Infant sleep patterns by sleep arrangement

After control of covariates, the mixed model analysis also showed a statistically significant association between sleep arrangement and infants' daytime, nighttime, and 24-hour sleep percentages (Table 3), but not between number of daytime naps and night waking, or maximum nocturnal sleep length (data not shown). Compared to bed-sharing, room-sharing was associated with greater daytime and 24-hour sleep percentage by 2.33% (equivalent of 33 minutes more per 24 hours) and 3.4% (equivalent of 27 minutes less per 24 hours), respectively (Table 3). However, this difference decreased over time as indicated by a statistically significant interaction with the rate of change (infant age, Table 3 and Fig. 3). Furthermore, sleeping alone was associated with greater nocturnal sleep percentage by 3.6 % (equivalent of 26 minutes less per 24 hours) compared to bed-sharing (Table 3), but this difference also decreased over time (Table 3 and Fig. 3).

Infant transitional objects

In our study sample, over 85% of infants needed a transitional object to go to sleep at bedtime regardless of the use of the feeding methods at each observation age (data not shown). The proportions for the infant sleep-onset aids needing to eat, sucking pacifiers or other items, rocking or patting, and sleeping in a lighted environment were 71.3%, 9.6%, 48.3%, 10.0% at 1 month, and 71.5%, 11.5%, 30.9%, 4.9% at eight months, respectively. There was a difference in the

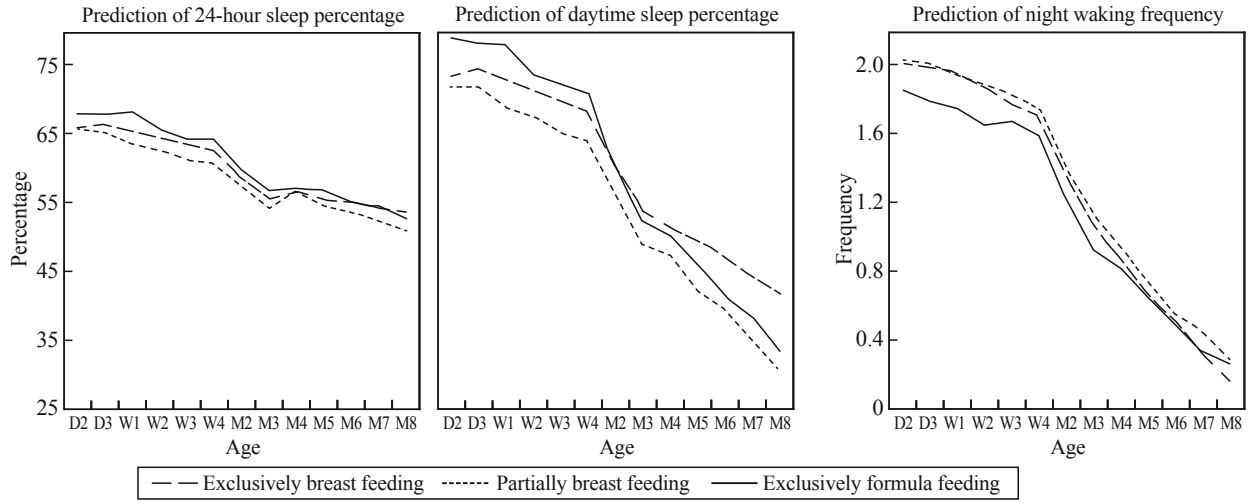

Fig. 2. Trajectories of 24-hour and daytime sleep percentages and night waking frequency by feeding method: based on mixed model analysis results in Table 2. The effects of exclusive breast feeding on 24-hour and daytime sleep percentage and freqency of night waking changed over time. The effects of partial breast feeding on 24-hour sleep percentage and nocturnal waking also vary over time.

types of transitional objects infants needed to sleep by feeding methods. During the first month after birth, PB infants had a higher rate of sucking pacifiers or other items at sleep onset than the other groups (PB: 16.7%, EB: 8.3%, EF: 2.0%; P=0.01, data not shown). At 3 months old at sleep onset, 67.0% of EB infants needed feeding, higher than 59.2% of PB, and 47.2% of EF (P=0.02, data not shown). At the same time, 9.3% of EB infants preferred sleeping in a lighted environment, a great proportion compared to PB (2.9%) and EF (0.0%) infants (P<0.05, data not shown). In addition, at five and eight months old, a greater percentage of EB infants needed feeding before sleep onset compared to PB and EF infants (p5 months old<0.05, and p8 months old=0.04. data not shown). After a night waking, the majority of infants in our study needed a help from a transitional object to go back to sleep. There were no statistically significant differences in the types of transitional objects infants needed to go back to sleep by feeding methods, except at 5 months of age, 83.8% of EB infants needed feeding, compared with 76.4% of PB, and 65.6% of EF infants (P=0.02, data not shown).

Discussion

In our study sample, feeding methods and sleep arrangements were associated with infants' sleep patterns, and infants' individual trajectories of sleep patterns varied over time. EF was associated with the greatest sleep percentage, followed by EB and PB. Night waking follows a similar pattern. In our longitudinal follow-up study, we also observed that the differences in sleep percentage and night waking frequency between exclusively formula and exclusively breast milk fed infants weakened over time as infants developed. In addition, we observed that room-sharing compared to bed-sharing was associated with the highest daytime and 24-hour infant sleep percentages.

Findings from our study are similar to those reported by prior research, albeit prior research had not included infants fed with breast milk partially. Quillin et al[26] demonstrated that breastfeeding was associated with less nighttime sleep in infants compared to formula feeding, but no difference was found in total 24-hour sleep at one month of age between breast-fed and formula-fed newborns. In another study with a larger sample size, Quillin and colleagues[9] observed that breast-fed infants experienced shorter total sleep time per day than formula-fed infants. Nevertheless, the study sample from Quillin et al[26] did not distinguish partially breast-fed infants in their assessment of feeding methods, which could result in misclassification of feeding methods. Interestingly, Cohen et al[11] recently reported that exclusive breast feeding of infants was associated with longer nighttime sleep. The authors suggested that this may have resulted from the substantial melatonin levels in nocturnal breast milk as compared to formula milk. But their findings were limited by cross-sectional study design and a small sample size of 94 infants.

Our observation of more frequent night wakings among partially breast-fed infants than exclusively formula-fed infants is also consistent with the finding from a number of previous studies.[4,7,12] Ball and colleagues[4] examined infant sleep patterns by feeding methods at one month and three months of age and reported that formula-fed infants' night wakings were 0.6-0.8 times less than breast-fed infants. In this study, breast-fed infants woke 2-3 times per night at one month after birth and night wakings decreased to 1-2 times at age of 3 months.[4] Increased night wakings

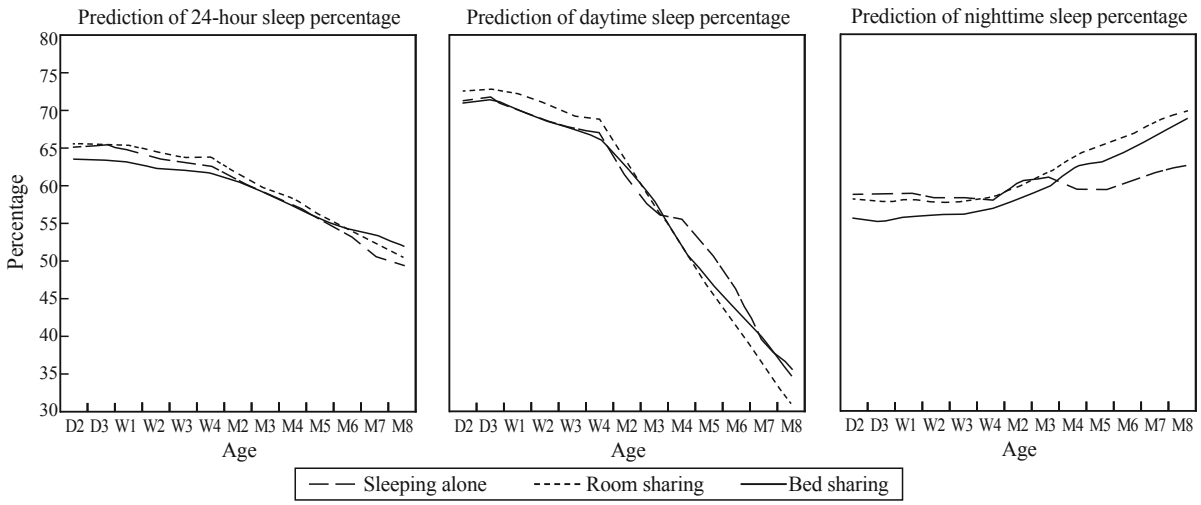

Fig. 3. Trajectories of 24-hour, daytime and nighttime sleep percentage by sleep arrangement: based on mixed model analysis results in Table 3.

among partially breast-fed infants in our study may be explained by more frequent infant feeding among partially breast-fed infants compared to exclusively formula-fed infants.

The benefits of breastfeeding for the development of infants are well established.[27] Breast feeding, which is a highly recommended maternal practice, has been associated with infants' more frequent night wakings and less self-soothing.[20] It has been postulated that milk protein from breast milk is more easily digestible than that in formula milk.[28] Future studies may assess feeding duration and volume and their relation to feeding methods, infant sleep patterns, and long-term growth outcomes. Consistent with previous findings, the observed association between feeding methods and nocturnal wakings in our study weakened as the infant matured.[29] Wright and associates[30] suggested that the difference in the attitude and expectations of parents with newborns who had night wakings may be more likely to account for the difference in breast- and formula-fed infants than any inherent difference in milk composition or amount consumed. In other words, the observed association between feeding methods and infant sleep patterns may be due to the developmental stages of sleep maturation and simply a response of parents as required. The inconsistent findings add to the challenges faced by health care professionals when advising parents with newborns on infant sleep patterns by feeding methods. The World Health Organization recommends exclusive breast feeding up till six months of age and that infants start receiving complementary foods at six months of age in addition to breast milk.[24] In light of the association between exclusively breast feeding and frequent night wakings from some studies, health care professionals need to work with parents of newborns to develop coping strategies to prevent early weaning of breast feeding before six months of age.

This study also found that bed-sharing was common in our study sample regardless of feeding methods. In contrast to our study, several previous studies in different populations have identified a positive association between breast feeding and bed-sharing.[14,15,31] Interestingly, our data indicated that sleeping-alone infants presented similar daytime and 24-hour sleep characteristics as bed-sharing infants. In addition, compared with bed-sharing, room-sharing was associated with greater 24-hour and daytime sleep percentages, whereas sleeping alone was associated with greater nocturnal sleep percentage. In a study on older school-age children, bed-sharing was also reported to correlate with shorter sleep duration, more bedtime resistance, sleep anxiety, parasomnia, sleep-disordered breathing, and daytime sleepiness.[32] Other studies[17,33] reported that nighttime waking frequency was associated with sleep arrangement. Mao et al[17] found that bed-sharing increased infants' night-time waking frequency by 2.6 times compared with sleeping alone. Some studies[34,35] suggested that bed-sharing infants, compared with sleeping-alone infants, had more physical contact with their caregivers. Presumably, their needs would be satisfied more quickly.[34,35] These studies suggested that the development of self-comfort capacity for bed-sharing infants would be lagging compared to sleeping-alone infants. They would have more difficultly going back to sleep after night waking compared with sleeping-alone infants.[34,35]

Sleep is influenced by both biological and cultural determinants.[36] In a large cross-culture study, Mindell and associates[36] reported that infants and toddlers in the predominantly Asian countries have less sleep and are more likely to bed-share or room-share than their counterparts from countries in the predominantly Caucasian regions. The authors suggested that the observed differences in sleep arrangement between the two groups may reflect the culture-based value of family interdependence in Asian countries that promotes room-sharing, as compared to an emphasis of independence in the western culture.[36] In Chinese culture, bed-sharing is perceived as family bonding and beneficial to a child's emotional development. Another important factor that may have influenced the high prevalence of bed-sharing practice in our study is China's one-child policy.[37] A study suggested that too much parental anxiety over a child's well-being could be a contributing factor to bed-sharing practice.[38] It has also been suggested that infants who were highly dependent on their mothers to sooth them had more sleep problems compared with infants who were less dependent.[39] Indeed, infants who require a high level of parental involvement and soothing at bedtime may fail to develop their own self-regulation and soothing skills and, therefore, continue to rely on repeated parental interventions during night waking.[20]

Strengths and limitations

It is noteworthy that the strengths of the present study included its prospective design with repeated assessment of infant sleep parameters, feeding methods, sleeping arrangements, and sleeping behaviors. The large sample size provided the present study adequate statistical power to detect significant associations and increased precision in the risk estimates. Studies[9-12] on feeding methods and infant sleep patterns were limited by small sample size, short-term follow up on infants' sleep, often with only one time assessment, and failure to examine the relationship between feeding methods or sleep arrangements and sleep patterns. But our data

should also be interpreted with caution. The attrition after the initial consent may limit the generalizability of our study findings. In addition, our analytical strategy did not account for the multi-stage sampling design, our findings are only generalizable to urban populations that share similar characteristics as our study sample. Measurement errors may be likely from the parental self-report data.[40] However, the misclassification in sleep parameters is probably non-differential, which will attenuate the point estimates toward the null. Additional longitudinal evaluations with more objective sleep measures, such as polysomnography or actigraphy, would enhance the validity of sleep measures. Nevertheless, the sleep diary has been validated as an effective method for collecting such data and its validity and feasibility have been examined in many studies.[41,42] Infants' sleeping and feeding methods could have mutual influence. Infant sleep arrangement and duration of sleep may impact on the caregiver's choice of feeding methods. Our study may be limited by lack of information on the reasons for different feeding types. However, our longitudinal data analysis did include repeated measures of both feeding methods and infant sleep patterns over time. Future research may concentrate on such information to understand if feeding style impacts sleep or if feeding style is altered by the caregiver to improve the sleep situation. Our study was also limited by lack of more detailed information on the volume or frequency of infant feeding. Residual confounding may be possible due to lack of information on infant's temperament, postpartum depression, parents' daily schedule, and sleeping environment such as ambient temperature.

Infant sleep is an important public health issue as sleep plays a critical role in a child's development and long-term health outcomes. Our data suggested that partial breast feeding and bed-sharing were associated with less infant sleep by about 30 minutes per 24 hours. Specifically, we observed that partial breast feeding, which is common, was associated with the least sleep percentages and greater night waking. Infant sleep related issues are of utmost concern to most new parents. The findings of our study based on a longitudinal follow-up add to the literature on normative patterns of infant sleep with the relationship to infant feeding and sleep arrangement. Parents with newborns could benefit from information about infant sleep patterns that might emerge and when to expect those changes at each developmental stage. A better understanding of the normative infant sleep patterns can aid health professionals in counseling parents on the variability in infant' sleep patterns and in establishing realistic expectations of infant sleep in this developmental process. Health professionals should also have an understanding of the common culture-based parenting practice of room-sharing or bed-sharing among Asian immigrants who hold these beliefs. Future studies on objective measurement of infant sleep are needed to verify our findings.

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