ORIGINAL ARTICLE

Breast feeding and respiratory morbidity in infancy: a birth cohort study

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Aim: To examine the relation between the duration of breast feeding and morbidity as a result of respiratory illness and infection in the first year of life.
Methods: Prospective birth cohort study of 2602 live born children ascertained through antenatal clinics at the major tertiary obstetric hospital in Perth, Western Australia. Main outcome measures were hospital, doctor, or clinic visits, and hospital admissions for respiratory illness and infection in the first year of life. Main exposure measures were the duration of predominant breast feeding (defined as the age other milk was introduced) and partial (any) breast feeding (defined as the age breast feeding was stopped). Main confounders were gender, gestational age less than 37 weeks, smoking in pregnancy, older siblings, maternal education, and maternal age.
Results: Hospital, doctor, or clinic visits for four or more upper respiratory tract infections were significantly greater if predominant breast feeding was stopped before 2 months or partial breast feeding was stopped before 6 months. Predominant breast feeding for less than six months was associated with an increased risk for two or more hospital, doctor, or clinic visits and hospital admission for wheezing lower respiratory illness. Breast feeding for less than eight months was associated with a significantly increased risk for two or more hospital, doctor, or clinic visits or hospital admissions because of wheezing lower respiratory illnesses.
Conclusions: Predominant breast feeding for at least six months and partial breast feeding for up to one year may reduce the prevalence and subsequent morbidity of respiratory illness and infection in infancy.

Breast feeding is clearly an issue for public health consideration as it provides significant protection against infections in newborns and infants.[1 2] Because breast feeding has been shown to protect against infections so profoundly in developing countries, it is estimated that an increase in breast feeding worldwide by 40% would reduce deaths from respiratory infection by 50% in children less than 18 months of age.[3]

Although breast feeding is associated with lower rates of both morbidity and mortality in the developing world,[2 4 5] evidence in the developed world has been and remains more controversial.[6 7] Yet, recent investigations show that respiratory tract infections[8–12] and asthma[13 14] are reduced in breast fed infants. On the other hand inverse relationships with breast feeding and health outcomes have been reported.

Respiratory infections and illness may be a risk factor for asthma in children[15] and their associated effects in relation to infant feeding need to be elucidated further. The effect of different feeding regimes was investigated in relation to respiratory infections and illness in a prospective birth cohort and following careful assessment of outcomes and exposures. We aimed to document the association of duration of predominant feeding and duration of any breast feeding with respiratory illness and infection morbidity as measured by doctor, hospital, or clinic visits and hospital admissions in the first year of life.

METHODS

Study population

The Western Australian Pregnancy Cohort Study was established between 1989 and 1992 as a prospective birth cohort study.[16] The cohort was serially recruited from the public antenatal clinic at King Edward Memorial Hospital, or nearby private practice in Perth, Western Australia. A total of 2979 women were enrolled at 18 weeks gestation. At the time of enrolment, data were collected from parents about their general and respiratory health and socioeconomic situation. By the end of the pregnancy phase 2888 women remained in the study, with 91 women having delivered elsewhere. Stillbirths and non-viable preterm births accounted for a further 28 pregnancies. Of 2860 live births, 13 infants (mostly neonates) had died, 154 had been withdrawn, and 81 (predominantly living overseas) had been lost to follow up. Thus 2602 out of 2860 (91%) children were available for follow up at 1 year of age. Informed consent was obtained for follow up of the children from birth.

Parents were provided with a diary card at the time of birth and were asked to complete the card on a daily basis throughout the first year by recording feeding history and illnesses. The illnesses recorded were those which required a visit to the hospital, doctor, or clinic, or hospital admission. At the end of the first year parents completed a questionnaire using the diary card as a prompt to recall events,[17] and their children were assessed for growth and development at the research clinic by a specially trained child health nurse. At the time of the one year assessment the nurse went through the questionnaire with the parent in a structured interview and transcribed feeding data as well as correct morbidity using ICD 9 codes for illnesses (age at completion of questionnaire: 13.9 (1.4) months).

At year one, 2456 questionnaires were received (82% of initial cohort; 94% of those consenting to follow up), and 2365 (79%; 91%) attended for clinical assessment. Of those parents who did not attend for clinical assessment (n = 91), questionnaire follow up was made by telephone.

Outcomes in the first year of life

Respiratory morbidity in the first year of life was the outcome of interest and included the number of doctor, hospital, or clinic visits, and the number of hospital admissions for any

respiratory illness or infection. Respiratory illness and infection were grouped as upper respiratory tract infection (unspecified upper respiratory tract infections, tonsillitis, otitis media, otitis media with effusion), wheezing lower respiratory tract illness (wheezing associated respiratory illness, bronchiolitis, bronchospasm, or asthma), and non-wheezing lower respiratory tract infection or illness (chest infection, any pneumonia, whooping cough, chronic cough, or croup). Hospital admission was considered for all groups as a measure of illness severity.[18]

Validation of hospitalisation data

A validation of 100 hospital admissions was conducted by checking parent report against the hospital case notes and morbidity coding, indicating that parental recall was 99% valid.

Exposures

Feeding data were recorded prospectively on the diary card by the parent and transcribed to the year one questionnaire by the nurse at the structured interview. Exposure to breast feeding was measured in two ways. Firstly, as the duration of predominant (or full) breast feeding defined by the age that any other milk (usually formula milk) was introduced (in months), and secondly as partial (or any) breast feeding defined by the age that breast feeding was stopped (in months).

We did not apply the World Health Organisation definition for exclusive breast feeding[19] where only breast milk and no other liquids or solids, not even water were given. We used the recommended definition for "predominant" breast feeding where breast milk plus water or water based fluids may have been given. We also used the definition for "partial" breast feeding (or any breast feeding) where other milk or formula had been given but breast feeding had not yet stopped.

The potential confounders that were adjusted in the analyses were gender (male:female), gestational age (<37 weeks:≥37 weeks), smoking in pregnancy (yes at 18 weeks and/or 34 weeks gestation:no), older siblings (yes:no), maternal education (<16 years education:≥16 years of education), and maternal age at the time of the infant birth (<20 years:≥20 years). Birth weight, attendance at childcare, father's occupation, family income, concurrent parental smoking, and parental history of asthma were considered as covariates but not included in the final models.

Statistical analysis and power

Statistical significance tests were based upon logistic regression[20] and a series of binary explanatory covariates. The study had >99% power to detect an odds ratio of 2.0 and >95% power to detect an odds ratio of 1.5 for most analyses.

RESULTS

Table 1 gives the prevalence of primary outcomes and exposures in the first year of life. Upper respiratory tract infections were common, with 60% having at least one, 28% having one to three, and 12% having four or more. Wheezing lower respiratory tract illnesses were less common, with 75% having none, 13% having one, and 12% having two or more. The non-wheezing lower respiratory infections were even less common (12%), with most of these cases being croup (5%). Only 1.5% of children were hospitalised for an upper respiratory tract infection, 3.4% (82 infants) for a wheezing illness, and 1.8% (45 infants) for a non-wheezing lower respiratory infection. Bronchiolitis was the most common cause of hospital admission (2%).

Almost half of the cohort (48%) ceased predominant breast feeding before 4 months or any breast feeding before 6 months. By 6 months 61% of mothers had stopped predominant breast feeding, and by 8 months 58% had stopped breast feeding altogether. By 12 months 5% of the cohort were still breast feeding predominantly, whereas 24% continued to partially breast feed. The mean age of formula introduction was 4.5 months (SD 3.8 months) and the mean age of breast feeding cessation was 7.5 months (SD 7.1 months), with the two variables highly correlated (Spearman's correlation: $r = 0.807$, $p = <0.001$).

Table 1 Prevalence of primary outcomes for respiratory morbidity and primary exposures in the first year of life

	Prevalence, n=2456 % (n)
Primary outcomes	
Hospital, doctor, or clinic visits for:	
Upper respiratory tract infection	
0–3	87.6 (2152)
≥4	12.4 (304)
Wheezing lower respiratory tract illness	
0–1	88.2 (2166)
≥2	11.8 (290)
Non-wheezing lower respiratory infection	
0	88.0 (2161)
≥1	12.0 (295)
Hospital admission for:	
Upper respiratory tract infection	1.5 (37)
Wheezing lower respiratory tract illness	3.4 (84)
Non-wheezing lower respiratory tract illness	1.8 (44)
Primary exposures	
Gender (male)	50.9 (1250)
Gestational age <37 wk	10.6 (260)
Smoking in pregnancy (at 18 and 34 wk)	40.3 (990)
Older siblings	49.6 (1218)
Maternal education (>16 years schooling)	35.0 (860)
Maternal age <20 y (mean age 28.12 y)	9.8 (241)
Duration of feeding regime	*(cumulative %)*
Predominant breast feeding stopped by:	
Never breast fed	10.6 (260)
Two months	26.9 (661)
Four months	48.4 (1189)
Six months	61.4 (1508)
Eight months	77.8 (1911)
Partial (any) breast feeding stopped by	
Never breast fed	10.6 (260)
Two months	21.2 (521)
Four months	37.7 (926)
Six months	48.0 (1179)
Eight months	58.2 (1429)

Table 2 shows crude and adjusted associations between predominant breast feeding and partial breast feeding at two dichotomisation cut points, with four or more hospital, doctor, or clinic visits or hospital admissions for upper respiratory infections. In adjusted analysis a shorter duration of predominant breast feeding (less than two months) was a risk factor for four or more hospital, doctor, or clinic visits because of upper respiratory tract infections (OR 1.43, 95% 1.02 to 2.01, $p = 0.041$), as was partial breast feeding for less than six months (OR 1.46, 95% CI 1.07 to 2.00, $p = 0.018$). Hospital admissions were associated with less than two months of predominant breast feeding in crude but not adjusted analysis.

Table 3 shows that following adjustment, predominant breast feeding for less than six months was significantly associated with two or more hospital, doctor, or clinic visits (OR 2.07, 95% CI 1.47 to 2.90, $p < 0.0005$) or hospital admission (OR 2.65, 95% CI 1.30 to 5.41, $p = 0.007$) because of wheezing lower respiratory illnesses. For two or more wheezing lower respiratory illnesses this effect continued until 8 months (OR 1.61, 95% CI 1.08 to 2.40, $p = 0.018$).

After adjustment, stopping breast feeding before 8 months was associated with an increased risk for two or more hospital, doctor, or clinic visits because of wheezing lower

Table 2 Multivariate relation between upper respiratory infections at 1 year of age (hospital, doctor, or clinic visits, and hospital admission) and duration of breast feeding

	Upper respiratory tract infections*							
	Four or more hospital, doctor, or clinic visits n=304/2456				Hospital admission n=37/2456			
	Crude		Adjusted†		Crude		Adjusted†	
Duration of feeding regime	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Predominant breast feeding <2 mth/2 mth+	1.39 (1.07 to 1.81)	0.014	1.43 (1.02 to 2.01)	0.041	2.47 (1.25 to 4.89)	0.009	1.85 (0.79 to 4.34)	0.158
Partial (any) breast feeding <6 mth/6 mth+	1.22 (0.94 to 1.59)	0.138	1.46 (1.07 to 2.00)	0.018	1.65 (0.83 to 3.33)	0.156	2.05 (0.88 to 4.76)	0.097

*Upper respiratory tract infection (otherwise non-specified), tonsillitis, otitis media, otitis media with effusion.
†Independent effect of feeding exposure after adjustment for gender, gestational age, smoking in pregnancy, older siblings, maternal education, and maternal age. Each estimated odds ratio is adjusted for the effect of all other exposure variables. Values are odds ratios (95% confidence intervals) with p value following. For each level of exposure, the stated odds ratio contrasts the odds of infection (the infection category in the column headings compared with none) in individuals exposed at the time defined in column one compared with all later times.

Table 3 Multivariate relation between wheezing lower respiratory illness at 1 year of age (hospital, doctor, or clinic visits or hospital admission) and duration of predominant breast feeding

	Wheezing lower respiratory tract illness*							
	Two or more hospital, doctor, or clinic visits n=290/2456				Hospital admission n=84/2456			
	Crude		Adjusted†		Crude		Adjusted†	
Duration of predominant breast feeding	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Never/ever	1.61 (1.13 to 2.29)	0.009	1.61 (1.05 to 2.48)	0.029	1.67 (0.91 to 3.07)	0.099	1.61 (0.73 to 3.54)	0.237
<2 mth/2 mth+	1.70 (1.32 to 2.19)	<0.0005	1.36 (0.99 to 1.88)	0.059	1.89 (1.20 to 2.96)	0.006	1.66 (0.92 to 3.01)	0.092
<4 mth/4 mth+	1.96 (1.49 to 2.56)	<0.0005	1.70 (1.25 to 2.30)	0.001	2.48 (1.48 to 4.20)	0.001	2.26 (1.23 to 4.16)	0.008
<6 mth/6 mth+	1.67 (1.22 to 2.28)	0.001	2.07 (1.47 to 2.90)	<0.0005	1.86 (1.02 to 3.40)	0.042	2.65 (1.30 to 5.41)	0.007
<8 mth/8 mth+	1.65 (1.18 to 2.32)	0.004	1.61 (1.08 to 2.40)	0.018	1.74 (0.91 to 3.32)	0.091	1.77 (0.78 to 3.99)	0.171

*Wheezing lower respiratory tract illness, bronchiolitis, bronchospasm, or asthma.
†Independent effect of feeding exposure after adjustment for gender, gestational age, smoking in pregnancy, older siblings, maternal education, and maternal age. Each estimated odds ratio is adjusted for the effect of all other exposure variables. Values are odds ratios (95% confidence intervals) with p value following. For each level of exposure, the stated odds ratio contrasts the odds of illness (the illness category in the column headings compared with none) in individuals exposed at the time defined in column one compared with all later times.

Table 4 Multivariate relation between wheezing lower respiratory illness at 1 year of age (hospital, doctor, or clinic visits or hospital admission) and duration of partial (any) breast feeding

	Wheezing lower respiratory tract illness*							
	Two or more hospital, doctor, or clinic visits n=290/2456				Hospital admission n=84/2456			
	Crude		Adjusted†		Crude		Adjusted†	
Duration of partial (any) breast feeding	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Never/ever	1.61 (1.13 to 2.29)	0.009	1.62 (1.06 to 2.49)	0.026	1.67 (0.91 to 3.07)	0.099	1.58 (0.72 to 3.47)	0.258
<2 mth/2 mth+	1.72 (1.33 to 2.22)	<0.0005	1.60 (1.14 to 2.24)	0.007	1.63 (1.04 to 2.56)	0.034	1.43 (0.75 to 2.73)	0.279
<4 mth/4 mth+	1.81 (1.41 to 2.33)	<0.0005	1.56 (1.14 to 2.12)	0.005	1.99 (1.26 to 3.12)	0.003	1.49 (0.83 to 2.67)	0.181
<6 mth/6 mth+	1.90 (1.46 to 2.48)	<0.0005	1.60 (1.17 to 2.17)	0.003	2.16 (1.33 to 3.52)	0.002	2.39 (1.30 to 4.42)	0.005
<8 mth/8 mth+	1.92 (1.46 to 2.52)	<0.0005	1.76 (1.27 to 2.44)	0.001	2.27 (1.32 to 3.89)	0.020	2.89 (1.44 to 5.80)	0.003

*Wheezing lower respiratory tract illness, bronchiolitis, bronchospasm, or asthma.
†Independent effect of feeding exposure after adjustment for gender, gestational age, smoking in pregnancy, older siblings, maternal education, and maternal age. Each estimated odds ratio is adjusted for the effect of all other exposure variables. Values are odds ratios (95% confidence intervals) with p value following. For each level of exposure, the stated odds ratio contrasts the odds of illness (the illness category in the column headings compared with none) in individuals exposed at the time defined in column one compared with all later times.

respiratory illnesses (OR 1.76, 95% CI 1.27 to 2.44, p = 0.001) or hospital admission for these illnesses (OR 2.89, 95% CI 1.44 to 5.80, p = 0.003) (table 4). Furthermore, stopping breast feeding before 12 months continued to be significantly associated with an increased risk for two or more hospital, doctor, or clinic visits because of wheezing lower respiratory illnesses (OR 1.63, 95% CI 1.11 to 2.41, p = 0.013) but not hospital admission (OR 2.13, 95% CI 0.94 to 4.82, p = 0.070).

Male gender, having older siblings, and maternal age were the only other identified risk factors that showed any association in any model (p < 0.05). The proxy measure of infection exposure, having older siblings, was associated with an increase in respiratory infection, illness, and associated hospital admissions. However, the inclusion of the other proxy measures of infection exposure, childcare, or playgroup attendance, did not change our conclusions. For completeness, secondary modelling showed that our substantive results in relation to either breast feeding variable were unaffected if family income or history of atopy were added to the models. The non-wheezing lower respiratory illnesses did not reach significance in relation to predominant or any breast feeding duration in any crude or multivariate model.

Hospital, doctor, or clinic visits or hospital admissions as a result of *any* respiratory infection or illness were combined as

composite variables reflecting any respiratory morbidity, and the protective effect of breast feeding persisted in all models ($p < 0.01$).

DISCUSSION

A strong association was evident for the protection of predominant or partial breast feeding against respiratory morbidity. Overall, the introduction of formula milk as well as any breast feeding for less than six months were found to be significant risk factors for hospital, doctor, or clinic visits and hospital admissions specifically for upper respiratory tract infections and wheezing lower respiratory tract illness. We interpret the pattern of reduced hospital admissions as evidence that breast feeding reduces the severity of respiratory morbidity.

The Western Australian Pregnancy Cohort Study has been previously shown to represent the general Western Australian population.[16] Mothers were enrolled in the study in mid-pregnancy (before any fetal outcomes were known), leaving little scope for selection bias. Drop out at birth because of early death or loss to follow up was rare (0.4%) and the study population was large with a high response rate. Collections of outcome data were prospective and at frequent intervals and were based on validated questionnaires and methodologies. Breast feeding and respiratory history were collected from a diary card and verified by nurse interview when the child was 1 year of age. Although diary cards have been used previously[17] and their validity documented,[21] we used diary cards as a tool for mothers in the recording of important events in their child's first year of life. No attempt was made to check compliance in the completion of the diary cards because of the number of mothers in the study.

We gathered data on confounders and applied multivariate modelling to adjust for them and the data set provided adequate power. While standardisation was performed for six principal covariates (gender, gestational age <37 weeks, smoking in pregnancy, older siblings, maternal education, and maternal age at time of birth), there were several other potential covariates. These included birth weight, mode of delivery, birth order, attendance at childcare, number of rooms in the house, father's occupation, family income, and parental history of asthma/atopy. When these variables were allowed for, the resulting ratios differed little from those adjusted for the six main covariates. Thus even after allowing for covariates, our findings support the conclusion that breast feeding has a substantial protective effect against respiratory infection and illness in the first year of life.

Studies of the relation between breast feeding and illnesses are subject to possible limitation by misclassification of exposure and outcome and by confounding. To correct for limitations, Bauchner *et al* suggested four standards for breast feeding studies.[22] These include avoidance of detection bias, clear definition of the outcome event, clear definition of breast feeding, and adjustment for potential confounding variables. All four recommended standards were met in our study, and the odds ratios consistently exhibited an expected direction of effect, suggesting biological plausibility and specific effects of breast milk.

Our data agrees with that of others,[12 23] that suggest that delaying the introduction of formula milk protects against the morbidity associated with respiratory infection, illness, and associated hospitalisations in the first year of life.[24] Prolonged breast feeding was only marginally associated with less respiratory illness when examined in a New Zealand birth cohort to 2 years of age,[25] and the Dundee study[8] showed a small, yet significant protective effect of breast feeding against respiratory illness at 0–13 weeks and 40–52 weeks after adjustment for social class, maternal age, and parental smoking. Although result trends were similar in these two studies, more precise breast feeding data collection in the latter study may account for any significant result differences.

Previous studies may not have shown any association due to lack of differentiation between wheezing and non-wheezing lower respiratory illness. The importance of viral infections is that they can trigger an acute episode of wheezing in children with asthma. Breast feeding for less than one month increased the incidence of respiratory syncytial virus infections,[10] as did male gender, room sharing, and mothers with lower level of education, but non-wheezing lower respiratory infections were not related to breast feeding patterns at any time in the first year in the same study.[26]

An earlier study reported no significant difference in rates of lower respiratory illness and associated hospital admissions between those never breast fed to those breast fed for three months or more after adjustment for maternal smoking.[6] However in this study, the breast feeding data were collected retrospectively and categorically at five years (never breast fed, <1 month, 1–2 months, 3+ months), and the true effect may have been obscured.

There are numerous prospective studies reporting the relation between breast feeding and respiratory morbidity (excluding allergic diathesis).[27–35] The advantages of our study are that feeding data were collected before disease outcomes were known, hospital admission data were validated, and the study had ample statistical power. In addition, a diary card was used for verification of illness and feeding history with the parent by the child health nurse at the one year structured interview.

It is reasonable to speculate that human milk may confer several effects on the development of the respiratory tract and its subsequent ability to fight infection and illness. Specific nutritional, immunoregulatory, and immunomodulatory factors in maternal milk may promote maturation of infant immune competence.[36 37] To support this, exclusive breast feeding has recently been observed to slow the involution of the thymus gland during infancy,[38] which is likely to have significant effects on systemic T cell function. Furthermore, bioactive factors impart defence to the newborn infant, adding biological plausibility to these findings.[39]

The optimal duration of exclusive breast feeding recently came under technical scrutiny during an expert WHO consultation. The consultation recommended exclusive breast feeding for six months, with introduction of complementary foods and continued breast feeding thereafter.[19] Given this recommendation, it is important that the role of exclusive, predominant, or any breast feeding duration in the prevention of childhood illness and infection is properly quantified and acknowledged. Formula fed infants have been shown to cost the health care system money,[24] but additional evidence and quantification of these costs are urgently required.

Our findings support the hypothesis that predominant breast feeding protects against the occurrence of respiratory infection and illness and associated hospital admissions in the first year of life. Although additional studies are required to confirm these findings and to understand the mechanisms of breast milk protection, public health interventions to promote predominant breast feeding for at least six months and any breast feeding up to one year may reduce the prevalence and subsequent morbidity of respiratory illness and infection in infancy.

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