



# Breastfeeding is Associated with Reduced Childhood Hospitalization: Evidence from a Scottish Birth Cohort (1997-2009)

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**Objective** To evaluate the risk of childhood hospitalization associated with infant feeding patterns at 6-8 weeks of age in Scotland.

**Study design** A retrospective population level study based on the linkage of birth, death, maternity, infant health, child health surveillance, and admission records for children born as single births in Scotland between 1997 and 2009 (n = 502 948) followed up to March 2012. Descriptive analyses, Kaplan Meier tests, and Cox regression were used to quantify the association between the mode of infant feeding and risk of childhood hospitalization for respiratory, gastrointestinal, and urinary tract infections, and other common childhood ailments during the study period.

**Results** Within the first 6 months of life, there was a greater hazard ratio (HR) of hospitalization for common childhood illnesses among formula-fed infants (HR 1.40; 95% CI 1.35-1.45) and mixed-fed infants (HR 1.18; 95% CI 1.11-1.25) compared with infants exclusively breastfed after adjustment for parental, maternal, and infant health characteristics. Within the first year of life and beyond, a greater relative risk of hospitalization was observed among formula-fed infants for a range of individual illnesses reported in childhood including gastrointestinal, respiratory, and urinary tract infections, otitis media, fever, asthma, diabetes, and dental caries.

**Conclusions** Using linked administrative data, we found greater risks of hospitalization in early childhood for a range of common childhood illnesses among Scottish infants who were not exclusively breastfed at 6-8 weeks of age. (*J Pediatr* 2015;166:620-5).

**B**reastfeeding enhances child health and development, with the potential to give every child a healthy start.<sup>1,2</sup> In developed countries however, there remains continued debate on the size of health benefit based on the available evidence, which has been limited by methodologic issues related to sample size, quality of data, or adjustment for confounding factors<sup>3-6</sup>; particularly socioeconomic factors associated with both the choice and duration of infant feeding and child health outcomes.<sup>3,4</sup>

As in the rest of the United Kingdom, increasing rates of childhood hospitalizations have been observed in Scotland, particularly for acute infections among infants.<sup>7,8</sup> These hospitalizations may contribute to substantial savings in the health service if breastfeeding rates increased marginally.<sup>9</sup> Current trends in Scotland, however, show relatively stable exclusive breastfeeding rates and an increasing proportion of mixed (formula and human milk) fed infants. Approximately one-half of infants born annually initiate exclusive breastfeeding, decreasing to 25% by the review at 6-8 weeks after birth.<sup>10</sup>

Based on linkage of administrative data for a population cohort of Scottish born infants, we describe patterns of hospitalization observed in early childhood in relation to the mode of infant feeding reported at 6-8 weeks after birth, adjusted for a range of socioeconomic factors. The analyses focus on hospitalization for a range of conditions in which breastfeeding has been shown to be protective<sup>6,11-13</sup> and, additionally, on conditions frequently reported in the cohort.

## Methods

This was a retrospective cohort study of singleton births in Scotland between 1997 and 2009 using anonymized extracts of linked administrative data provided by the Information Services Division, National Health Service National Services Scotland. Approval for the project design and confidentiality of patient data was provided by the Privacy Advisory Committee of National Health Service

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HR Hazard ratio  
PAF Population-attributable fraction

National Services Scotland, a body set up to ensure the appropriate use of patient identifiable information.<sup>14</sup> Further ethical permission was not required.

The records were linked in 2 phases via a combination of probabilistic matching techniques and the use of the Community Health Index, a unique identifier developed for health records in Scotland.<sup>15</sup> Phase 1 comprised linkage of births, deaths, migration, maternity, infant health, and child health surveillance review records,<sup>16</sup> which was extended in Phase 2 to include episodes of hospital admission from birth until March 2012. Thus, each child in the cohort could be followed up from birth for at least 2.25 years and up to 15 years (depending on their birth year).

Infants with a diagnosis of congenital anomaly, a condition originating in the perinatal period, with invalid infant feeding records, and of non-Scottish residents were excluded from analysis.

### Outcome Variables

The main outcome examined was a primary discharge diagnosis for selected conditions from a review of literature, including gastrointestinal infections, lower and upper respiratory tract infections, otitis media, asthma, urinary tract infections, allergy, eczema, and diabetes, and conditions frequently reported in the cohort such as fever and dental caries (Table I; available at [www.jpeds.com](http://www.jpeds.com)).

### Definition of Infant Feeding

Infant feeding reported at the 6-8 weeks of age review, defined as the predominant mode of infant feeding on the day preceding data collection, was divided into 3 categories: “exclusive breastfeeding,” “formula feeding,” and “mixed-breast and formula feeding.”

### Statistical Analyses

Descriptive and univariate (Kaplan Meier curves) analyses were used to identify variables associated with hospital admission and infant feeding. Multivariate analyses (Cox regression analyses) were conducted to quantify the independent contribution of infant feeding at the 6-8 week review on hospitalization in childhood. The Cox models included only variables significantly associated with the health outcome from the univariate analyses. Each model was tested for proportionality over time, adjustments were made to ensure the best fit, and violations noted.

Adjustment was made for parental factors, delivery and infant health characteristics, and features of the health care system.<sup>16</sup> In addition, area deprivation derived using postcode at birth based on the Scottish Index of Multiple Deprivation (2006<sup>17</sup>) and maternal ethnic and religious background derived from the mother’s given name (ie, OnoMAP<sup>18</sup>) were included in the analyses. Additional analysis was conducted to assess the risk of hospitalization for injuries (a condition not causally associated with breastfeeding), to test the adequacy of adjustment for socioeconomic and demographic confounders included in the linked dataset.

A series of models were applied over varying periods of follow-up (using STATA vs11; StataCorp LP, College Station, Texas) to estimate the risk of hospital admission associated with infant feeding patterns: up to 6 months (that reflects the recommended duration of exclusive breastfeeding), 6-27 months (point of “equal” follow-up for all infants in the cohort), and up to 15 years (full-follow-up). An estimate of the time from birth to event (ie, first hospital admission) was derived from the merged datasets and a marker applied to infants who had a hospital admission. Those who had migrated or died before the end of the observation period (March 2012) were censored from follow-up at the point of migration/death. The variables were entered into the model iteratively ie, infant feeding at the 6- to 8-week review was entered first, followed by parental/background variables, then delivery and infant health variables. The model entry significance was 0.05. Population-attributable fractions (PAFs) were used to quantify the number of new cases that may have been avoided among formula fed children in each model using the formula:  $PAF = [(hazard\ ratio\ [HR] - 1)/HR] \times proportion\ of\ the\ exposed\ population$ .

## Results

Of the 502 948 singletons born between 1997 and 2009 included in the analysis, 63% were born by spontaneous/normal delivery, 8% had teenage mothers, 17% were born to single parents or parents living apart, 45% were born to first-time mothers, 22% had mothers who smoked, and 27% were residents in the most socioeconomically deprived areas at birth (Table II; available at [www.jpeds.com](http://www.jpeds.com)). By the review at 6-8 weeks of age, 27% of infants were reported as exclusively breastfeeding, 9% as having mixed feeding, and 64% as formula-feeding.

During the study period, 137 905 (27%) of the infants had been hospitalized at least once for any of the selected conditions. At the first recorded hospital event, 31% were younger than 1 year, 29% were 1-2 years, 19% were 3-5 years, and 21% were aged 5 years or older. Most of the first hospital events were “emergency admissions” (75%), especially among infants <1 year of age at admission (98%).

Infants exclusively breastfed at the 6-8 week review were older at first admission (mean: 178 days; IQR: 74-275 days) and had a shorter length of stay (mean: 2.81 days; IQR: 1.0-3.5 days) compared with formula-fed infants (mean age: 164.6 days; IQR: 66-255 days and mean stay: 3.25 days; IQR: 1.0-4.0 days) and mixed-fed infants (mean age: 172.5 days; IQR: 70-263 days and mean stay: 3.08 days; IQR: 1-3 days). The crude rates of hospitalization were 21%, 24%, and 31% among exclusively breastfed, mixed fed, and formula-fed infants, respectively.

### Multivariate Analyses

For any of the selected conditions, infants who were reported as formula and mixed fed at the 6-8 week review had a significantly greater relative risk of hospital admission, particularly

within 6 months of birth (Table III; available at [www.jpeds.com](http://www.jpeds.com)). There was also a greater relative risk of hospital admission among infants resident in more deprived areas (within 6 months of birth), of fathers with a semiroutine/routine occupation, of single parents/parents living apart, and among infants with siblings (within 6 months of birth). Preterm infants, those born by cesarean delivery, infants of low birth weight, and those admitted to a neonatal unit also had a relatively greater risk of hospital admission. Conversely, risk of infant admission decreased with increasing maternal age.

On the basis of adjusted PAF, 21% of hospital admissions within the first 6 months of birth might have been averted if formula fed infants had been exclusively breastfed until the 6-8 week review. The estimated PAFs were lower among older infants—10% for formula fed infants between 6 and 27 months and 13% during the full follow-up period.

### Gastrointestinal, Respiratory, Urinary Tract Infections, Fevers, and Otitis Media

During the full follow-up period, the rates of hospital admissions for gastrointestinal, upper, and lower respiratory tract infections were 21%, 26%, and 25%, respectively. At the first admission event, more than two-thirds of the cohort admitted for gastrointestinal, lower, and upper respiratory tract infections was younger than 2 years. There was a lower prevalence of hospital admissions for urinary tract infections, fevers, and otitis media (3%, 3%, and 6%, respectively). Formula-fed infants had a greater rate of hospital admission for each of the infections studied.

The adjusted relative risk remained significantly greater among formula-fed infants for hospital admission for gastrointestinal, lower and upper respiratory infections, urinary tract infections, and otitis media, which occurred within 6 months of birth. Similarly, an increased risk of hospitalization was observed among these conditions and for fever at 6-27 months; the results for otitis media were not statistically significant (Table IV).

Within 6 months of birth, the proportion of hospitalizations that may have been averted among formula-fed infants, based on the PAF estimates, was 41% for otitis media, 27% for gastrointestinal infections, 22% for lower respiratory tract infections, and 16% for both upper respiratory and urinary tract infections.

### Allergies, Eczema, and Asthma

During the study period, 4% of the cohort was hospitalized for asthma and 1% each for allergies and eczema. Infants aged less than 1 year made up 49% and 26% of the first-time admissions for eczema and allergies, respectively. More than one-half (58%) of the admissions for asthma occurred among children aged 3 years or older. Formula-fed infants had an increased (adjusted) relative risk of hospitalization for allergies within 6 months of birth. Similarly, an increased risk of hospital admission was observed for asthma among older infants (admitted aged 6-27 months).

In contrast, there was a relatively lower risk of hospital admission among formula-fed infants admitted for eczema within 6 months of birth and for allergies beyond 6 months (Table IV). Infant feeding was not significant in the models of hospitalization for eczema among older children.

### Diabetes and Dental Caries

There were 1132 children in the study cohort (0.2%) hospitalized for diabetes during the study period. Approximately 1 in 10 (9%) of those hospitalized for diabetes were younger than 2 years of age at the first admission (1% aged <1 year) and 62% were  $\geq 5$  years of age.

During the full follow-up period, the relative risk of admission for diabetes was 1.28 (95% CI 1.09-1.49) among children who were formula fed at the 6-8 week review; there also was an increased HR for those aged 5 years or older at first admission (HR 1.39; 95% CI 1.13-1.71; not shown).

There were 38 650 children in the cohort admitted for dental caries during the study period (8% of the cohort), 95% of whom were aged 3 years or older at the first admission. During the full follow-up period, the adjusted models showed a 48% greater relative risk of admission for dental caries among formula-fed infants (HR 1.48; 95% CI 1.43-1.53). This result accounted for 27% of the hospitalizations for dental caries that might have been averted if formula-fed infants had been exclusively breastfed until the 6-8 week review, all other factors remaining constant (Table IV).

### Injuries

Hospital admissions related to injuries were analyzed as a control group. There were 45 177 children admitted for injuries from the cohort during the study period. After adjustment for other factors, infant feeding was not a significant predictor of hospital admission (HR 1.00; 95% CI 0.98-1.02).

## Discussion

This study of a representative sample of Scottish births (1997-2009) confirms evidence of the association between infant feeding choices (reported at 6-8 weeks) and childhood hospitalization and remained significant after adjustment for a range of socioeconomic factors. It also estimates the proportion of hospital admissions attributable to not breastfeeding exclusively, in the cohort, particularly hospitalizations within the first 6 months of life.

Respiratory and gastrointestinal infections comprised 79% of the selected causes of hospitalization (and 38% of all hospital admissions in the birth cohort); greater rates were reported among infants <1 year of age, consistent with the recently reported trends in pediatric admissions.<sup>7,8</sup>

After adjustment for parental and other factors, we found a greater risk of hospitalization among formula-fed infants as has been observed by others for each of the infections: gastrointestinal,<sup>6,11-13,19-22</sup> upper and lower respiratory tract

**Table IV.** Risk of hospitalization for selected conditions and feeding at the 6-8 wk review

| Mode of infant feeding at the 6-8 wk review | Crude HR         |                    | Adjusted HR       |                    |           |                     |                    |     |                                   |                    |     |
|---|------------------|--------------------|-------------------|--------------------|-----------|---------------------|--------------------|-----|-----------------------------------|--------------------|-----|
|   | All infants/ages |                    | Infants aged ≤6 m |                    |           | Infants aged 6-27 m |                    |     | Full follow-up (all infants/ages) |                    |     |
|   | HR               | 95% CI             | HR                | 95% CI             | PAF       | HR                  | 95% CI             | PAF | HR                                | 95% CI             | PAF |
| <b>Gastrointestinal infections</b>          |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          |                   |                    |           |                     |                    |     |                                   |                    |     |
| Mixed fed                                   | 1.18             | (1.12-1.25)        | <b>1.18</b>       | <b>(1.03-1.34)</b> | <b>1%</b> | 1.17                | (1.08-1.26)        | 1%  | 1.13                              | (1.07-1.19)        | 1%  |
| Formula fed                                 | 1.60             | (1.55-1.65)        | 1.59              | (1.47-1.73)        | 27%       | 1.34                | (1.28-1.41)        | 17% | 1.31                              | (1.26-1.35)        | 18% |
| <b>Upper respiratory tract</b>              |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | —                   | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | 1.19             | (1.13-1.24)        | <b>1.03</b>       | <b>(0.89-1.20)</b> | —         | 1.13                | (1.05-1.21)        | 1%  | 1.13                              | (1.08-1.18)        | 1%  |
| Formula fed                                 | 1.44             | (1.40-1.48)        | 1.28              | (1.17-1.40)        | 16%       | 1.19                | (1.14-1.25)        | 11% | 1.21                              | (1.18-1.25)        | 9%  |
| <b>Lower respiratory tract infections</b>   |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | 1.13             | (1.08-1.18)        | 1.18              | (1.07-1.30)        | 1%        | 1.09                | (1.02-1.17)        | 1%  | 1.07                              | (1.02-1.12)        | 1%  |
| Formula fed                                 | 1.39             | (1.35-1.43)        | 1.50              | (1.41-1.59)        | 22%       | 1.11                | (1.06-1.16)        | 7%  | 1.14                              | (1.11-1.18)        | 9%  |
| <b>Urinary tract infections</b>             |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | <b>1.14</b>      | <b>(1.00-1.30)</b> | <b>1.25</b>       | <b>(0.99-1.59)</b> | —         | <b>1.11</b>         | <b>(0.89-1.38)</b> | —   | <b>1.13</b>                       | <b>(0.99-1.30)</b> | —   |
| Formula fed                                 | 1.42             | (1.32-1.54)        | 1.46              | (1.25-1.71)        | 16%       | 1.29                | (1.13-1.46)        | 15% | 1.35                              | (1.24-1.47)        | 14% |
| <b>Otitis media</b>                         |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | <b>1.07</b>      | <b>(0.98-1.17)</b> | <b>1.50</b>       | <b>(0.65-3.48)</b> | —         | <b>1.00</b>         | <b>(0.83-1.18)</b> | —   | <b>1.04</b>                       | <b>(0.95-1.14)</b> | —   |
| Formula fed                                 | 1.11             | (1.05-1.17)        | 2.13              | (1.26-3.59)        | 41%       | <b>1.00</b>         | <b>(0.89-1.12)</b> | —   | <b>1.03</b>                       | <b>(0.97-1.09)</b> | —   |
| <b>Asthma</b>                               |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | 1.11             | (1.00-1.22)        | <b>1.73</b>       | <b>(0.41-7.29)</b> | —         | <b>1.14</b>         | <b>(0.93-1.40)</b> | —   | <b>1.01</b>                       | <b>(0.91-1.12)</b> | —   |
| Formula fed                                 | 1.25             | (1.17-1.32)        | <b>2.06</b>       | <b>(0.77-5.46)</b> | —         | 1.15                | (1.01-1.31)        | 10% | <b>0.98</b>                       | <b>(0.92-1.05)</b> | —   |
| <b>Allergies</b>                            |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | 0.76             | (0.62-0.94)        | <b>1.15</b>       | <b>(0.94-1.42)</b> | —         | <b>0.75</b>         | <b>(0.53-1.04)</b> | —   | 0.63                              | (0.55-0.72)        | —   |
| Formula fed                                 | 0.55             | (0.48-0.62)        | 1.20              | (1.06-1.37)        | 6%        | 0.51                | (0.41-0.64)        | —   | 0.73                              | (0.59-0.91)        | —   |
| <b>Eczema</b>                               |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed feeding                               | <b>0.92</b>      | <b>(0.74-1.16)</b> | <b>0.83</b>       | <b>(0.58-1.20)</b> | —         | <b>0.77</b>         | <b>(0.52-1.13)</b> | —   | <b>0.89</b>                       | <b>(0.77-1.02)</b> | —   |
| Formula feeding                             | <b>1.06</b>      | <b>(0.93-1.20)</b> | 0.73              | (0.57-0.92)        | —         | <b>0.89</b>         | <b>(0.71-1.12)</b> | —   | <b>0.81</b>                       | <b>(0.65-1.02)</b> | —   |
| <b>Diabetes</b>                             |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed feeding                               | <b>1.18</b>      | <b>(0.92-1.52)</b> |                   | N/A (n = 4)        | —         | <b>1.39</b>         | <b>(0.74-2.61)</b> | —   | <b>1.22</b>                       | <b>(0.94-1.57)</b> | —   |
| Formula feeding                             | 1.22             | (1.05-1.42)        |                   |                    | —         | <b>0.79</b>         | <b>(0.50-1.26)</b> | —   | 1.28                              | (1.09-1.49)        | 15% |
| <b>Fever</b>                                |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | 1.15             | (1.05-1.25)        | <b>1.28</b>       | <b>(0.99-1.65)</b> | —         | 1.15                | (1.03-1.29)        | 1%  | 1.10                              | (1.00-1.20)        | 1%  |
| Formula fed                                 | 1.36             | (1.29-1.43)        | <b>1.13</b>       | <b>(0.95-1.35)</b> | —         | 1.26                | (1.17-1.35)        | 14% | 1.16                              | (1.10-1.23)        | 10% |
| <b>Dental caries</b>                        |                  |                    |                   |                    |           |                     |                    |     |                                   |                    |     |
| Excl breastfed                              | 1.00             | Reference          | 1.00              | Reference          | —         | 1.00                | Reference          | —   | 1.00                              | Reference          | —   |
| Mixed fed                                   | 1.34             | (1.27-1.42)        |                   |                    | —         | <b>0.72</b>         | <b>(0.46-1.11)</b> | —   | 1.15                              | (1.09-1.21)        | 1%  |
| Formula fed                                 | 2.63             | (2.55-2.72)        |                   | No cases           | —         | <b>1.02</b>         | <b>(0.79-1.31)</b> | —   | 1.48                              | (1.43-1.53)        | 27% |

Excl, exclusive; ISD, Information Services Division; n/a, not applicable.

(—) refers to variables excluded from the model. Variables in bold were not significant ( $P > .05$ ) or violated the assumption of proportionality required by Cox regression analyses (bold and in italics). Source: ISD Scotland linked data extract.

infections,<sup>6,19-22</sup> urinary tract infections,<sup>12</sup> otitis media,<sup>12,13,23</sup> fevers often associated with an underlying infection,<sup>24,25</sup> and, for other conditions such as asthma,<sup>26-28</sup> diabetes,<sup>29,30</sup> and dental caries.<sup>31,32</sup> These patterns could be attributed to the components of human milk, which provide immunologic protection<sup>6,33</sup> and delay exposure to environmental contaminants or pathogenic micro-organisms.<sup>33</sup>

Furthermore, compared with breastfed infants, mixed- and formula-fed infants were younger and stayed longer when admitted to hospital.<sup>20,34</sup> There also was a greater relative risk of hospital admission among infants with siblings, of fathers of a lower socioeconomic status, of single parent households,<sup>34,35</sup> preterm infants, and those born

via cesarean delivery and of a small weight for gestational age.<sup>36</sup>

The relatively lower risk of hospitalization for eczema and allergies among formula-fed infants aged 6 months or older was contrary to the plausible mechanisms for its action<sup>37</sup> and the findings of some<sup>13,26-28,38,39</sup> but not all<sup>40,41</sup> studies. This “inverse” pattern may be associated with influences not measured in our study (eg, prenatal sensitization, family history,<sup>42</sup> parental knowledge and health seeking behavior,<sup>43</sup> vitamin D deficiency,<sup>44</sup> exposure to environmental contaminants, or the age that solid foods were introduced). It is also possible that the duration of breastfeeding, ie, measured at 6-8 weeks, was insufficient to detect a beneficial outcome.

In addition to the large sample size and wide coverage, this study, based on routinely collected data, had the advantage of a wide range of relevant variables, including area and individual-level socioeconomic characteristics. This made it possible to observe the influence of both individual and area-based socioeconomic factors in the analyses, which often confounds the complex relationship between infant feeding and child health. As expected, the risk of hospital admission significantly increased with greater deprivation. However, further analyses, stratifying the results by area deprivation (not shown) and controlling for other parental, maternal, and infant health characteristics, confirmed a greater risk of hospital admission among formula-fed compared with exclusively breastfed infants in both the least-deprived (HR 1.38 95% CI 1.33-1.42) and most-deprived areas (HR 1.46 95% CI 1.41-1.51), albeit with an effect modification that may be due to residual confounding. In addition, the modeling of hospitalizations for injuries—not causally associated with infant feeding—suggests that the adjustment for socioeconomic confounders was sufficient.

Although the coverage and completeness of variables using the routine datasets was relatively high, the study was limited to an extent by the availability of confounders on the linked dataset and uncertainty over the overall duration and the definition of infant feeding. An attempt was made to adjust for variation in the age at review, but it was not possible to account for the “exclusivity” or exact duration of feeding, and hence, to fully model the dose-response effect. Minimal violations to the assumption of proportionality noted in this study may relate to unmeasured covariates and their association with other covariates.<sup>45</sup>

Overall, it is likely that there is an underestimation of the association between formula feeding and hospitalization as not all ill health conditions observed in children result in hospitalization<sup>46</sup> and other studies include parent observation in the definition of disease,<sup>11,19,22</sup> which was not possible in this study. Furthermore, using the main diagnoses at hospital discharge (a probable marker of severity) along with the variation in coding practices between hospitals<sup>21</sup> may have moderated the observed associations of infant feeding on early child health.

Limitations in the data set preclude a full debate on causality and the protective effects of exclusive breastfeeding. Nevertheless, the strength of association between breastfeeding and reduced infant morbidity, which is consistent with other studies, provides convincing evidence of the benefits of breastfeeding on child health in the context of developed countries. This study also highlights the utility of administrative datasets and the need to enhance their quality for child health research in Scotland. ■

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## Appendix

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**Table I.** ICD-10 codes for selected outcomes

| Ill health condition               | ICD-10 codes (main diagnoses)   |
|------------------------------------|---|
| Gastrointestinal infections        | A02, A03, A04, A05, A06, A08, A09X, K529, K521, K522, K528, P783, R11X, P920                      |
| Upper respiratory tract infections | J00X, J01, J02, J03, J04, J05, J06, J101, J111  |
| Lower respiratory tract infections | J10, J11, J12, J13X, J14X, J15, J16, J17, J18, J20, J22X, R062, J100, J110, J40X, J41, J42X, R05X |
| Urinary tract infections           | N390, N30, N34  |
| Otitis media                       | H65, H66, H67   |
| Asthma                             | J45, J46X   |
| Allergy                            | T784, T781, T887, J301, J302, J303, J304, J450, L23, K522, T780, T782, T783, T886                 |
| Eczema                             | L20, L21, L22X, L23, L24, L25, L26X, L27, L28, L29, L30   |
| Diabetes                           | E10, E11, E12, E14, E14, P702   |
| Fever                              | R560, R509  |
| Dental caries                      | K029  |

ICD-10, *International Classification of Diseases, 10th revision.*

**Table II.** Cohort characteristics and rates of infant feeding and hospital admission

|                                | Cohort  |     | Infant feeding at 6-8 wk (rates) |                  |                    | Rate of admission, % |
|--------------------------------|---------|-----|----------------------------------|------------------|--------------------|----------------------|
|                                | N       | %   | Excl breastfeeding, %            | Mixed feeding, % | Formula feeding, % |                      |
| Maternal age, y                |         |     |                                  |                  |                    |                      |
| Less than 20                   | 40 127  | 8   | 6                                | 3                | 90                 | 36                   |
| 20-24                          | 91 135  | 18  | 14                               | 6                | 81                 | 33                   |
| 25-29                          | 133 101 | 26  | 25                               | 9                | 66                 | 28                   |
| 30-34                          | 147 436 | 29  | 36                               | 11               | 54                 | 24                   |
| 35-39                          | 76 617  | 15  | 39                               | 12               | 49                 | 23                   |
| 40+ years                      | 13 870  | 3   | 41                               | 13               | 47                 | 22                   |
| Area deprivation               |         |     |                                  |                  |                    |                      |
| SIMD A Least deprived quintile | 87 674  | 17  | 45                               | 12               | 42                 | 21                   |
| SIMD B                         | 86 574  | 17  | 38                               | 11               | 51                 | 24                   |
| SIMD C                         | 87 358  | 17  | 29                               | 9                | 62                 | 26                   |
| SIMD D                         | 104 587 | 21  | 21                               | 8                | 72                 | 29                   |
| SIMD E most deprived quintile  | 136 751 | 27  | 13                               | 6                | 81                 | 33                   |
| Mother's country of birth      |         |     |                                  |                  |                    |                      |
| British                        | 462 627 | 92  | 25                               | 8                | 67                 | 28                   |
| Non-British                    | 40 305  | 8   | 49                               | 19               | 32                 | 20                   |
| Mother's socioeconomic status  |         |     |                                  |                  |                    |                      |
| Higher manger/professional     | 139 430 | 28  | 47                               | 12               | 41                 | 22                   |
| Intermediate                   | 115 032 | 23  | 26                               | 9                | 65                 | 26                   |
| Semiroutine/routine            | 142 718 | 28  | 15                               | 6                | 79                 | 31                   |
| Student                        | 8963    | 2   | 23                               | 10               | 67                 | 26                   |
| Other/unknown                  | 96 805  | 19  | 19                               | 7                | 74                 | 32                   |
| Father's socioeconomic status  |         |     |                                  |                  |                    |                      |
| Higher manger/professional     | 146 605 | 29  | 45                               | 12               | 43                 | 22                   |
| Intermediate                   | 83 850  | 17  | 32                               | 10               | 58                 | 25                   |
| Semiroutine/routine            | 220 571 | 44  | 17                               | 7                | 76                 | 31                   |
| Student                        | 5358    | 1   | 36                               | 13               | 50                 | 22                   |
| Other/unknown                  | 46 564  | 9   | 11                               | 5                | 83                 | 35                   |
| Marital status                 |         |     |                                  |                  |                    |                      |
| Married                        | 272 231 | 54  | 37                               | 11               | 52                 | 24                   |
| Cohabiting                     | 146 831 | 29  | 19                               | 7                | 73                 | 29                   |
| Single/parents living apart    | 83 886  | 17  | 9                                | 4                | 87                 | 35                   |
| Parity                         |         |     |                                  |                  |                    |                      |
| No siblings/first child        | 224 370 | 45  | 26                               | 9                | 64                 | 27                   |
| One sibling                    | 164 987 | 33  | 28                               | 8                | 63                 | 27                   |
| 2 or more (to 16 siblings)     | 94 812  | 19  | 27                               | 8                | 65                 | 29                   |
| Other/unknown                  | 18 779  | 4   | 31                               | 10               | 60                 | 25                   |
| Maternal smoking               |         |     |                                  |                  |                    |                      |
| Nonsmoker                      | 356 865 | 71  | 33                               | 10               | 57                 | 25                   |
| Smoker                         | 110 512 | 22  | 9                                | 5                | 86                 | 35                   |
| Other/unknown                  | 35 571  | 7   | 28                               | 8                | 64                 | 29                   |
| Neonatal admission             |         |     |                                  |                  |                    |                      |
| Not admitted                   | 434 819 | 86  | 28                               | 9                | 63                 | 27                   |
| Admitted for up to 48 h        | 15 742  | 3   | 23                               | 8                | 70                 | 33                   |
| Admitted for more than 48 h    | 20 403  | 4   | 19                               | 9                | 72                 | 37                   |
| Other/unknown                  | 31 984  | 6   | 29                               | 10               | 61                 | 28                   |
| Mode of delivery               |         |     |                                  |                  |                    |                      |
| Normal/spontaneous             | 318 442 | 63  | 28                               | 8                | 64                 | 28                   |
| Instrumental                   | 60 025  | 12  | 29                               | 10               | 61                 | 26                   |
| Breech births                  | 1037    | 0.2 | 22                               | 9                | 69                 | 33                   |
| Cesarean, elective             | 42 160  | 8   | 26                               | 10               | 65                 | 28                   |
| Cesarean, emergency            | 65 963  | 13  | 25                               | 10               | 65                 | 28                   |
| Other/unknown                  | 79      | 0.0 | 25                               | 13               | 62                 | 18                   |
| Maternal religious background  |         |     |                                  |                  |                    |                      |
| Christian                      | 477 941 | 95  | 27                               | 8                | 65                 | 28                   |
| Muslim                         | 13 793  | 3   | 37                               | 25               | 38                 | 26                   |
| Buddhist                       | 3120    | 1   | 41                               | 19               | 40                 | 19                   |
| Sikh                           | 1346    | 0.3 | 50                               | 24               | 26                 | 18                   |
| Hindu                          | 1397    | 0.3 | 29                               | 19               | 52                 | 22                   |
| Jewish                         | 316     | 0.1 | 34                               | 13               | 53                 | 22                   |
| Other                          | 5035    | 1   | 37                               | 16               | 47                 | 23                   |

Excl, exclusive; SIMD, Scottish Index of Multiple Deprivation.



**Table III.** Risk of hospitalization for specific childhood conditions (1997-2009 birth cohort)\*

| Parental, maternity, and infant health variables | Follow-up period, HR (95% CI) |                         |                         |
|--|-------------------------------|-------------------------|-------------------------|
|  | 6 mo                          | 6-27 mo                 | Full follow-up          |
| Feeding at 6-8 wk                                |                               |                         |                         |
| Excl breastfeeding                               | 1.00                          | 1.00                    | 1.00                    |
| Mixed feeding                                    | 1.18 (1.11-1.25)              | <b>1.11 (1.07-1.15)</b> | 1.11 (1.08-1.14)        |
| Formula feeding                                  | 1.40 (1.35-1.45)              | <b>1.18 (1.15-1.21)</b> | 1.24 (1.22-1.26)        |
| Sex  |                               |                         |                         |
| Male   | 1.00                          | 1.00                    | 1.00                    |
| Female   | —                             | 0.80 (0.78-0.81)        | 0.84 (0.83-0.85)        |
| Maternal age range, y                            |                               |                         |                         |
| Less than 20                                     | 1.00                          | 1.00                    | 1.00                    |
| 20-24  | 0.87 (0.82-0.91)              | <b>0.99 (0.95-1.03)</b> | 0.97 (0.95-0.99)        |
| 25-29  | 0.69 (0.65-0.73)              | 0.94 (0.90-0.97)        | 0.90 (0.88-0.92)        |
| 30-34  | 0.60 (0.57-0.64)              | 0.87 (0.83-0.91)        | 0.84 (0.82-0.86)        |
| 35-39  | 0.53 (0.50-0.57)              | 0.83 (0.79-0.87)        | 0.81 (0.79-0.83)        |
| 40+  | 0.44 (0.40-0.49)              | 0.81 (0.76-0.88)        | 0.78 (0.75-0.82)        |
| Area deprivation                                 |                               |                         |                         |
| SIMD A_Least deprived quintile                   | 1.00                          | 1.00                    | 1.00                    |
| SIMD B   | <b>1.04 (0.99-1.10)</b>       | 1.05 (1.02-1.09)        | 1.09 (1.07-1.12)        |
| SIMD C   | 1.08 (1.03-1.14)              | <b>1.01 (0.98-1.05)</b> | 1.11 (1.08-1.13)        |
| SIMD D   | 1.11 (1.06-1.17)              | 1.07 (1.03-1.10)        | 1.17 (1.15-1.20)        |
| SIMD E_Most deprived quintile                    | 1.11 (1.06-1.17)              | <b>1.02 (0.99-1.06)</b> | 1.19 (1.17-1.22)        |
| Mother's country of birth                        |                               |                         |                         |
| British birth                                    | 1.00                          | 1.00                    | 1.00                    |
| Non-British birth                                | —                             | 0.87 (0.83-0.91)        | 0.87 (0.84-0.89)        |
| Father's country of birth                        |                               |                         |                         |
| British birth                                    | 1.00                          | 1.00                    | 1.00                    |
| Non-British birth                                | —                             | 0.93 (0.88-0.97)        | 0.92 (0.89-0.94)        |
| Other unknown                                    | —                             | <b>1.05 (0.98-1.12)</b> | <b>1.02 (0.98-1.06)</b> |
| Mother's socioeconomic status                    |                               |                         |                         |
| Higher managerial/professional                   | 1.00                          | 1.00                    | 1.00                    |
| Intermediate                                     | <b>0.95 (0.91-0.99)</b>       | <b>0.99 (0.96-1.02)</b> | 1.02 (1.01-1.04)        |
| Routine/semiroutine                              | <b>1.01 (0.97-1.05)</b>       | <b>0.97 (0.94-1.00)</b> | 1.09 (1.07-1.11)        |
| Students   | <b>0.98 (0.88-1.08)</b>       | <b>0.95 (0.88-1.02)</b> | <b>0.99 (0.95-1.04)</b> |
| Not stated                                       | 1.08 (1.03-1.13)              | 0.93 (0.90-0.96)        | 1.09 (1.07-1.11)        |
| Father's socioeconomic status                    |                               |                         |                         |
| Higher managerial/professional                   | 1.00                          | 1.00                    | 1.00                    |
| Intermediate                                     | 1.05 (1.00-1.10)              | <b>1.01 (0.98-1.04)</b> | 1.07 (1.05-1.09)        |
| Routine/semiroutine                              | 1.08 (1.04-1.12)              | 1.06 (1.04-1.09)        | 1.17 (1.15-1.19)        |
| Students   | <b>0.99 (0.87-1.14)</b>       | <b>0.94 (0.85-1.04)</b> | <b>0.94 (0.88-1.01)</b> |
| Not stated                                       | 1.16 (1.09-1.23)              | <b>1.01 (0.95-1.08)</b> | 1.12 (1.08-1.16)        |
| Marital status                                   |                               |                         |                         |
| Married  | 1.00                          | 1.00                    | 1.00                    |
| Cohabiting                                       | <b>1.02 (0.99-1.06)</b>       | 1.04 (1.01-1.06)        | 1.04 (1.02-1.06)        |
| Single/living apart                              | 1.14 (1.09-1.19)              | 1.08 (1.04-1.12)        | 1.13 (1.11-1.15)        |
| Maternal smoking status                          |                               |                         |                         |
| Nonsmoker  | 1.00                          | 1.00                    | 1.00                    |
| Smoker   | —                             | 1.05 (1.02-1.08)        | 1.11 (1.09-1.12)        |
| Other unknown                                    | —                             | 0.87 (0.84-0.90)        | <b>0.99 (0.96-1.01)</b> |
| Parity   |                               |                         |                         |
| First birth                                      | 1.00                          | 1.00                    | 1.00                    |
| One sibling                                      | 1.46 (1.41-1.51)              | <b>0.98 (0.96-1.01)</b> | 1.04 (1.03-1.06)        |
| 2-16   | 1.70 (1.63-1.77)              | <b>1.01 (0.98-1.04)</b> | 1.10 (1.08-1.12)        |
| Other unknown                                    | 1.47 (1.27-1.69)              | 1.13 (1.01-1.25)        | 1.10 (1.03-1.17)        |
| Mode of delivery                                 |                               |                         |                         |
| Normal/spontaneous delivery                      | 1.00                          | 1.00                    | 1.00                    |
| Instrumental                                     | <b>0.95 (0.91-0.99)</b>       | <b>1.01 (0.97-1.04)</b> | <b>1.00 (0.98-1.02)</b> |
| Breech births                                    | <b>0.90 (0.70-1.16)</b>       | <b>1.18 (0.99-1.42)</b> | <b>1.04 (0.93-1.17)</b> |
| Cesarean emergency                               | 1.24 (1.18-1.30)              | 1.18 (1.14-1.23)        | 1.14 (1.12-1.17)        |
| Cesarean elective                                | 1.06 (1.01-1.10)              | 1.10 (1.07-1.14)        | 1.06 (1.04-1.08)        |
| Other unknown                                    | <b>0.29 (0.04-2.06)</b>       | <b>0.72 (0.30-1.74)</b> | <b>0.67 (0.38-1.18)</b> |
| Maternal religious background                    |                               |                         |                         |
| Christian  | 1.00                          | 1.00                    | 1.00                    |
| Muslim   | —                             | <b>1.06 (0.99-1.14)</b> | 1.18 (1.13-1.23)        |
| Buddhist   | —                             | 0.82 (0.70-0.97)        | <b>0.97 (0.88-1.07)</b> |
| Hindu  | —                             | <b>0.92 (0.73-1.16)</b> | <b>0.92 (0.80-1.07)</b> |
| Sikh   | —                             | <b>0.87 (0.70-1.08)</b> | <b>0.88 (0.78-1.00)</b> |
| Jewish   | —                             | <b>0.92 (0.62-1.38)</b> | <b>0.84 (0.65-1.09)</b> |
| Other  | —                             | 0.85 (0.76-0.95)        | <b>0.94 (0.88-1.00)</b> |

(continued)

Table III. Continued

| Parental, maternity, and infant health variables | Follow-up period, HR (95% CI) |                         |                         |
|--|-------------------------------|-------------------------|-------------------------|
|  | 6 mo                          | 6-27 mo                 | Full follow-up          |
| Weight/gestational age                           |                               |                         |                         |
| Normal weight/gestational age                    | 1.00                          | 1.00                    | 1.00                    |
| Small for gestational age                        | —                             | 1.06 (1.01-1.12)        | 1.05 (1.01-1.08)        |
| Birth weight                                     |                               |                         |                         |
| Greater than 2500 g                              | 1.00                          | 1.00                    | 1.00                    |
| Less than 2500 g                                 | 1.16 (1.09-1.24)              | 1.10 (1.04-1.16)        | 1.08 (1.04-1.11)        |
| Estimated gestation                              |                               |                         |                         |
| Normal   | 1.00                          | 1.00                    | 1.00                    |
| Preterm  | 1.45 (1.37-1.55)              | 1.30 (1.24-1.37)        | 1.19 (1.15-1.23)        |
| Postterm   | <b>0.72 (0.44-1.20)</b>       | <b>0.88 (0.64-1.23)</b> | <b>0.99 (0.82-1.19)</b> |
| Neonatal admission                               |                               |                         |                         |
| Not admitted                                     | 1.00                          | 1.00                    | 1.00                    |
| Admitted to 48 h                                 | 1.18 (1.11-1.27)              | 1.12 (1.07-1.18)        | 1.14 (1.11-1.17)        |
| Admitted >48 h                                   | 1.33 (1.25-1.42)              | 1.13 (1.08-1.19)        | 1.17 (1.14-1.21)        |
| Other unknown                                    | 1.13 (1.05-1.21)              | 1.09 (1.03-1.14)        | 1.12 (1.09-1.16)        |
| Baby friendly                                    |                               |                         |                         |
| Not accredited                                   | 1.00                          | 1.00                    | 1.00                    |
| Fully accredited                                 | —                             | 0.68 (0.66-0.69)        | —                       |
| Length of postnatal stay, d                      |                               |                         |                         |
| <2   | 1.00                          | 1.00                    | 1.00                    |
| 3-5  | 0.96 (0.93-0.99)              | 0.94 (0.92-0.96)        | 0.97 (0.96-0.98)        |
| 6-20   | <b>1.02 (0.96-1.09)</b>       | <b>0.99 (0.94-1.04)</b> | <b>0.99 (0.96-1.02)</b> |
| Other unknown                                    | <b>0.80 (0.59-1.08)</b>       | <b>1.08 (0.90-1.30)</b> | <b>0.94 (0.83-1.08)</b> |
| Month of birth                                   |                               |                         |                         |
| July-September                                   | 1.00                          | 1.00                    | 1.00                    |
| January-March                                    | —                             | —                       | 0.96 (0.94-0.97)        |
| April-June                                       | —                             | —                       | 0.97 (0.95-0.98)        |
| October-December                                 | —                             | —                       | <b>1.01 (0.99-1.02)</b> |

ISD, Information Services Division.

(—) refers to variables excluded from the model, variables in bold were not significant ( $P > .05$ ) or violated the test of proportionality required for Cox analysis (bold and in italics).

Adjusted for infant feeding, area deprivation, infant sex, maternal age range, area deprivation, mother's country of birth, father's country of birth, mother's socioeconomic status, father's socioeconomic status, marital status, maternal smoking status, parity, mode of delivery, maternal religious background, weight for gestational age, birth weight, estimated gestation, neonatal admission indicator, birth in baby friendly facility, maternal postnatal stay in hospital, month of birth.

\*Selected conditions outlined in Table I.

Source: ISD Scotland linked data extract.