Association between breastfeeding duration and educational achievement in England: results from the Millennium Cohort Study

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ABSTRACT
Objective To evaluate the association between breastfeeding duration and educational outcomes at the end of secondary education among children from the Millennium Cohort Study.

Design Cohort study comparing school results at age 16 according to breastfeeding duration.

Setting England.


Exposure Self-reported breastfeeding duration (categorised).

Main outcome measures Standardised school assessments taken at the end of secondary education (General Certificate of Secondary Education (GCSEs), marked 9–1) in English and Mathematics, categorised as: ‘fail, marks <4’, ‘low pass, marks 4–6’ and ‘high pass, marks ≥7 (equivalent to A–A*)’. Additionally, overall achievement was measured using the ‘attainment 8’ score (adding the marks of eight GCSEs, English and Mathematics double weighted; 0–90).

Results Approximately 5000 children were included. Longer breastfeeding was associated with better educational outcomes. For example, after full adjustment for socioeconomic markers and maternal cognitive ability, in comparison with children who were never breastfed, those who were breastfed for longer were more likely to have a high pass in their English and Mathematics GCSEs, and less likely to fail the English GCSE (but not the Mathematics GCSE). Additionally, compared with those never breastfed, those breastfed for at least 4 months had, on average, a 2–3 point higher attainment 8 score (coefficients: 2.10, 95% CI 0.65 to 4.14 at 4–6 months; 2.56, 95% CI 0.65 to 4.47 at 6–12 months and 3.09, 95% CI 0.84 to 5.35 at ≥12 months).

Conclusions A longer breastfeeding duration was associated with modest improvements in educational outcomes at age 16, after controlling for important confounders.

INTRODUCTION
There is some evidence that breastfeeding (BF) duration is associated with improved child’s cognitive development, even after accounting for important confounders, such as socioeconomic position (SEP) and maternal intelligence. However, not all studies observe significant differences between breastfeeding groups after adjustment for these confounders, and among those that do, the effect sizes tend to be modest. Consequently, the importance of breastfeeding for improving cognitive outcomes continues to be debated. Educational attainment is related to cognitive ability, and is a strong predictor of life trajectories. Researchers have hypothesised that breastfed children would have better school results than non-breastfed children, although the empirical evidence is inconsistent.

In developed economies, including the UK, mothers from a higher SEP are more likely to breastfeed, and to have children who perform better in school. A study analysing 16 British cohorts found that a lower socioeconomic background was associated with poorer academic performance. Maternal intelligence is also an important confounder in the association of interest. While maternal intelligence is partly explained by SEP, strong evidence supports its heritability. Hence, its standalone confounding role has been recognised. However, the majority of published studies did not adjust for this variable.

Studies in the different British birth cohorts have found a positive association between breastfeeding and school results. For those born in 1946, breastfed babies scored higher in English/Mathematics tests at age 15, and were more likely to have higher educational qualifications at 26. For those born in 1991, BF was positively associated with national examinations’ scores at ages 7, 11 and 14.
Similarly, studies analysing those born in the early 2000s (Millennium Cohort Study, MCS) found breastfeeding to be positively associated with school readiness at age 389 and a statutory test at age 5.10 However, none of these studies adjusted for maternal cognitive ability, and to our knowledge, studies exploring the association in the MCS have only analysed outcomes at the time of entry to the education system.8–10 Therefore, the present study evaluated the association between breastfeeding duration and educational outcomes at age 16 among children from the MCS in England.

METHODS
Study population, design and setting
The MCS enrolled 18,818 children born in 2000–2002 and living in the UK, who were followed-up at ages 3, 5, 7, 11, 14, 17 and 22.23 The present study analysed participants from England due to the differences in educational assessment between UK countries, and up to age 14 for survey data and age 16 for educational data. The MCS sampled a nationally representative cohort, and oversampled children from disadvantaged and ethnic minority backgrounds.24 Singleton, term babies were included, for whom an English-speaking mother was the main respondent. Participants were included if they were present at follow-up at age 7 (consent for educational data requested), and age 14 (maternal cognitive performance measured).

Exposure
The exposure was the duration of any breastfeeding (maternal report), categorised as: never breast fed, <2, 2 to <4, 4 to <6, 6 to <12 and ≥12 months, to examine potential patterns in the association, such as dose-response relationships, and to explore what might be the minimal BF duration associated with improved academic achievement.

Outcomes
The MCS has been linked with the National Pupil Dataset (NPD), which stores longitudinal academic data of students enrolled in English state schools.25 The English national curriculum provides a framework to be followed by all state-funded schools, and encompasses five key stages of learning (KS1–5).2627 This study evaluated educational attainment in KS4 (ages 14–16, assessed at age 16).

KS4 ends with the assessment of the child’s educational achievement through standardised tests in different subjects (General Certificate of Secondary Education, GCSE).2728 The MCS children were examined in the transition from letter grading (A*–E) to numeric grading (9–1). GCSEs in English and Mathematics were marked in a 9–1 scale (9: highest performance; ≥4: pass). The rest of the subjects were marked in an 1–5 marks within the NPD. The final score adds the marks (range: 0–90).272830 All participants with a score of zero were excluded.

Confounding
This study attempts to estimate the overall effect of breastfeeding on schooling outcomes; therefore, potential confounders were identified through a literature review, and the hypothesised underlying relationships (mediators not shown) were described using a directed acyclic graph (figure 1). The variables considered (categories in table 1) included:

1. A priori confounders: SEP markers, indicated by the highest parental social class and maternal education (National Vocational Qualifications; gestational age at birth, maternal ethnicity, language spoken at home, child’s sex and age.
2. Other potential confounders: older siblings in the household, mother smoked during pregnancy, maternal age, employment, relationship status, Index of Multiple Deprivation.
3. Maternal verbal cognitive performance: proxy for cognitive ability evaluated when the participants were aged 14 years. The mothers’ understanding of the meaning of 20 words was assessed through a vocabulary test (standardised: x̄=0, SD=1).31

Except for age and maternal cognitive performance, all variables were measured at baseline.

Missing data
The most common reason for missing data was loss to follow-up (unit non-response). Differential non-response and attrition were corrected using longitudinal survey weights (age 14), thus minimising the risk of selection bias.32 Among those followed up to age 14, <5% had missing data for confounders. Considering this proportion was low, we followed a complete-case approach.

Statistical analysis
The association between BF duration and the schooling results was first evaluated using X² (categorical outcomes) and the Wald test/F-statistic (attainment 8, continuous). To estimate the association between breastfeeding duration and English/Maths GCSEs, we fitted multinomial models to calculate relative risk ratios (RRR), comparing ‘fail’ and ‘high pass’, with ‘low pass’ (reference), comparing the different categories of breastfeeding duration with non-BF children, while adjusting for confounders. To evaluate the association between breastfeeding duration and five GCSE passes (binary) and attainment 8 (continuous), modified Poisson regression was used to generate risk ratios (RR) and linear regression to estimate coefficients, respectively.

Confounder adjustment followed a sequential approach, adding the variables in blocks as outlined above. Model one was adjusted for the confounders identified a priori, then additional variables were included if they remained associated with the outcome (p<0.10), after full adjustment. Different models were fitted for English, Mathematics and general outcomes. The final and fully adjusted model incorporated maternal cognitive scores (model 2). All analyses were conducted in Stata 17.0 and considered the complex sampling design, and attrition weights.24

RESULTS
Descriptive results
Of the 11,695 children enrolled in the MCS, 7645 were successfully linked to education data. A further 2402 children did not fulfil the eligibility criteria, and of these, 1292 were excluded because they were not followed up at age 14. 4940 children with complete data were included in the analyses (figure 2, online supplemental material 1).

The mean age at baseline was 9.2 months; 32.8% were never breast fed, and 9.5% were breast fed for ≥12 months. Half
(49.2%) of the mothers had only secondary education, and 22.6% were in the semiroutine/routine social class. Approximately, one-third of participants failed their English (32.6%) and Mathematics (31.2%) GCSEs; 15.9% and 18.8% achieved a high pass (marks ≥7) in English and Mathematics, respectively; 56.4% passed five GCSEs with marks ≥5, and the average attainment 8 score was 47.1 (SD 18.9) (table 1).

Children breast fed for longer were more likely to have older and more educated mothers, of higher social class. They were also less likely to have mothers that identified as White and spoke only English at home (table 1). The associations between covariates and outcomes are shown in online supplemental materials 2 and 3.

**Association between breastfeeding duration and academic results**

**English GCSE**

There is an apparent dose–response association between longer BF durations and being less likely to fail and more likely to have a high pass. For example, 19.2% of those BF for ≥12 months failed English compared with 41.7% of those never BF; 28.5% of those BF for ≥12 months achieved a high pass compared with 9.6% among non-breastfed participants (table 1). In crude models, compared with those not BF, the relative risk reductions (RRRs) for a high pass increased from 1.32 (95% CI 1.02 to 1.70) for BF <2 months to 2.77 (95% CI 2.08 to 3.71) for BF ≥12 months. Adjustment explained most of the observed associations (RRR: 0.98; 95% CI 0.83 to 1.27 for BF <2 months, and RRR: 1.38; 95% CI 1.00 to 1.90 for BF ≥12 months) (figure 3). There was a similar dose–response association for failing compared with achieving a low pass. Again, after adjustment, only a borderline association remained in those who were BF for ≥12 months (RRR: 0.75; 95% CI 0.55 to 1.00).

**Mathematics GCSE**

For Mathematics, there was not a clear gradient between BF duration and failing. After adjustment, those breast fed for 4–6 months were less likely to fail in comparison with those never BF (0.72; 95% CI 0.52 to 0.99) (figure 3). However, this was not the case for those BF ≥12 months (RRR: 1.00, 95% CI 0.74 to 1.35).

There was a strong dose–response association between BF duration and having a high pass. After adjustment, the association weakened, although those breast fed for ≥12 months (vs non-breast fed) were 39% more likely to have a high pass than a lower pass (RRR: 1.39; 95% CI 1.01 to 1.90).

**Five GCSEs with marks ≥5**

In the crude analysis, all BF infants were more likely to pass five GCSEs than those never BF. The effect was similar for all those BF for ≥4 months: they were 1.6 times more likely to achieve this than those never BF. Adjustment attenuated the effect, but the association persisted for durations ≥4 months (RR: 1.13; 95% CI 1.02 to 1.23) (figure 4).

**Attainment 8**

There was a dose–response relationship between BF and the attainment 8 score. After adjustment, compared with those non-BF, those BF for ≥4 months had, on average, a 2–3 point higher attainment 8 score (coefficients: 2.10, 95% CI 0.06 to 4.14 for 4–6 months; 2.56, 95% CI 0.65 to 4.47 for 6–12 months; and
Table 1  Characteristics of the study participants according to their breastfeeding duration (n=4940) among children from the UK Millennium Cohort Study (England)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Descriptive</th>
<th>Duration of any breastfeeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole sample</td>
<td>Never BF (n=1200) (32.8%)</td>
</tr>
<tr>
<td>Pregnancy and child-related</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age at birth‡</td>
<td>39.8 (1.3)</td>
<td>39.8 (1.1)</td>
</tr>
<tr>
<td>Female</td>
<td>2517 (49.9)</td>
<td>641 (52.3)</td>
</tr>
<tr>
<td>Age at key stage 4‡</td>
<td>16.2 (0.3)</td>
<td>16.2 (0.3)</td>
</tr>
<tr>
<td>No older siblings</td>
<td>2492 (51.2)</td>
<td>546 (48.0)</td>
</tr>
<tr>
<td>Smoked during pregnancy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>3515 (64.4)</td>
<td>703 (51.8)</td>
</tr>
<tr>
<td>Gave up</td>
<td>601 (13.4)</td>
<td>148 (12.8)</td>
</tr>
<tr>
<td>Kept smoking</td>
<td>824 (22.2)</td>
<td>349 (35.4)</td>
</tr>
<tr>
<td>Moderate/heavy alcohol in pregnancy§</td>
<td>370 (7.7)</td>
<td>94 (0.8)</td>
</tr>
<tr>
<td>Sociodemographic, age 9m.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attainment 8 score‡ ††</td>
<td>47.1 (18.9)</td>
<td>41.4 (15.3)</td>
</tr>
<tr>
<td>Socioeconomic, age 9m.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal relationship status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>3220 (57.9)</td>
<td>601 (41.4)</td>
</tr>
<tr>
<td>Cohabitation</td>
<td>1196 (27.9)</td>
<td>372 (34.6)</td>
</tr>
<tr>
<td>Single mother</td>
<td>524 (12.4)</td>
<td>227 (24.0)</td>
</tr>
<tr>
<td>Not applicable</td>
<td>194 (5.0)</td>
<td>83 (8.7)</td>
</tr>
<tr>
<td>Maternal Cognitive Score‡</td>
<td>0.0 (1.0)</td>
<td>-0.42 (0.72)</td>
</tr>
<tr>
<td>Maternal education¶</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>568 (15.3)</td>
<td>256 (27.0)</td>
</tr>
<tr>
<td>Lower (NVQ 1 and 2)</td>
<td>2238 (49.2)</td>
<td>729 (59.9)</td>
</tr>
<tr>
<td>Medium (NVQ 3)</td>
<td>471 (8.5)</td>
<td>59 (4.0)</td>
</tr>
<tr>
<td>Higher (NVQ 4 and 5)</td>
<td>1551 (25.0)</td>
<td>131 (7.7)</td>
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<tr>
<td>Maternal ethnicity: White</td>
<td>4174 (89.6)</td>
<td>1082 (93.9)</td>
</tr>
<tr>
<td>Language spoken at home</td>
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<td></td>
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<tr>
<td>English only</td>
<td>4305 (92.0)</td>
<td>1100 (95.1)</td>
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<tr>
<td>English+other language</td>
<td>635 (8.0)</td>
<td>100 (4.9)</td>
</tr>
<tr>
<td>Index of Multiple Deprivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P value†Whole sample</td>
<td>0.0 (1.0)</td>
<td>-0.42 (0.72)</td>
</tr>
</tbody>
</table>

Note: *Parameters were estimated considering the complex design of the Millennium Cohort Study sample. The counts reflect the absolute number of participants included.
†X2 or mean difference, as appropriate.
‡Mean (SD).
§Consumption of ≥3 units per week or ≥3 units per occasion during pregnancy.
¶National Vocational Qualifications (NVQ): NVQ 4 and 5: higher/university education, NVQ3: A-levels, qualifications obtained at age 18, NVQ 1 and 2: qualifications obtained at age 16, at the end of secondary education.
**Five GCSEs passed with marks ≥5, including English and Mathematics.
††Attainment 8 is the additive score of the marks of a student in their best eight GCSEs, including English and Mathematics (double weighted) and can range between 0 and 90.
BF, breastfeeding; GCSE, General Certificate of Secondary Education.
The association between breastfeeding and schooling results

Longer BF was associated with modest gains in academic outcomes. The strength of the association equates to a 38–39% increase in the probability of achieving high marks in both GCSEs and a 25% reduction in the probability of failing (English). The gains in the probability of passing five or more GCSEs were smaller (13% increase). The difference of approximately 3 points in attainment 8 scores (out of 90) between extreme categories of breastfeeding duration is also modest.

Previous studies have found similar associations, with comparable or stronger effect sizes.3–17 The effect seems to be present in studies that evaluated attainment at the beginning of the school system,5–10 in primary school,7,11–13,16,17 near the end of secondary school1,5,7,13,18,19 and later in life.4,6,14 However, the different nature of the outcomes hinders comparability: early-life school readiness assessments are not directly comparable to standardised tests taken in secondary school, or with the number of years of schooling completed by age 30. However, most studies seem to suggest a positive association between breastfeeding and schooling results.3–17 Comparability may also be limited by heterogeneity in the ‘non-breasted’ group, who could receive cow’s milk, other liquids and/or formula, which are time and region-dependent.

Several mechanisms may explain the association between breastfeeding and educational outcomes. The main mechanism proposed is through improved cognitive development.3,6,13,19 Breast milk contains polyunsaturated fatty acids and micronutrients, which enhance neurodevelopment.34 Adjustment for cognitive abilities at age 15 explained a considerable portion of association in the 1946 British birth cohort, which may indicate mediation.6 However, education may also be a marker of cognitive ability. Similarly, breastfeeding was associated with intergenerational upward social mobility (change in occupational social class) in the 1958 and 1970 British birth cohorts, and this effect was mediated by cognitive performance.34 It has also been proposed that breastfeeding may enable mother–child bonding,11,13,15,17,33 which would favour both cognitive and academic performance. Another hypothesis includes mediation by improvements in self-regulation, which can predict academic achievement.15

Confounding

Some propose that the observed association is mostly/solely due to confounding,2 predominantly by SEP and maternal intelligence.12 In the present study, adjustment for SEP had the greatest explanatory effect. Further adjustment for maternal cognitive abilities explained a smaller portion of the association. A recent MCS study found that adjustment for maternal cognitive abilities explained a seemingly higher fraction of the association with cognitive outcomes35—compared with its smaller explanatory power with educational outcomes in the present study. This suggests that socioeconomic circumstances may play a bigger role than maternal cognitive ability in predicting school results in the UK. In cohort studies from low- and middle-income countries, where SEP is negatively (or not) associated with breastfeeding duration, breastfeeding did not predict schooling outcomes.18,19 Additionally, in the 15-year time gap between exposure and outcome, SEP could have created other conditions that influence the schooling results, and/or accentuated the differences between breastfed and non-breastfed groups, thus influencing the observed associations. These evolving conditions are difficult to capture and deserve deeper exploration.

While SEP seems to be the strongest confounder, adjustment for maternal cognitive abilities also explained some of the association. This is important to consider when interpreting the results of most previous studies, as control for this variable is rare.3–16,19

Strengths and limitations

Our findings are nationally representative for children enrolled in state schools in England. The large sample size allowed us to detect outcome differences between several breastfeeding duration groups. Additionally, the outcomes

3.09 to 95% CI 0.84 to 5.35 for those BF for ≥12 months (figure 4).

DISCUSSION

Summary of key findings

This study evaluated the association between breastfeeding duration and school results at age 16 in England. We observed modest dose–response relationships, where children breast fed for longer were more likely to achieve high marks and less likely to fail their examinations. Additionally, children breast fed for ≥4 months were more likely to pass five GCSEs than non-breastfed children, and also scored higher in the consolidated (additive) mark for their GCSEs.
were both subject-specific and general measures of achievement, assessed by the English education system, and have direct relevance to future opportunities. We have also comprehensively controlled for the confounding effect of several markers of family-level and area-level SEP, and maternal cognitive abilities.

![Figure 3](attachment:image.png) **Figure 3** Association between breastfeeding duration and key stage 4 (KS4) results at age 16 in English (n=5026) and Mathematics (n=5012) GCSEs*, Millennium Cohort Study (MCS). *Parameters were estimated considering the complex design of the MCS sample, using multinomial regression, where 'obtaining low passing marks (excluding A to A*)' was the reference outcome category. Model 1: adjusted for sex, age at KS1, maternal ethnicity and language spoken in the household, socioeconomic position (maternal education and highest social class in the household), Index of Multiple Deprivation, older siblings in the household, mother working outside the home, partnership status, smoking during pregnancy (Mathematics: model 3 also includes maternal age and maternal alcohol use during pregnancy), Model 2: adjusted for model 1 + Maternal Cognitive Score.

![Figure 4](attachment:image.png) **Figure 4** Association between breastfeeding duration and key stage 4 (KS4) results at age 16: Passing five GCSEs with marks ≥5, including English and Mathematics (n=5012) and attainment 8 score (n=4940)** ¶, Millennium Cohort Study (MCS). *Parameters were estimated considering the complex design of the MCS sample. Model 1: adjusted for sex, age at KS4, maternal ethnicity and language spoken in the household, socioeconomic position (maternal education and highest social class in the household), Index of Multiple Deprivation, older siblings in the household, maternal age, mother working outside the home, partnership status, smoking and alcohol use during pregnancy. Model 2: adjusted for model 1 + Maternal Cognitive Score. ¶Attainment 8 is the additive score of the marks of a student in their best eight GCSEs, including English and Mathematics (double weighted), and can range between 0 and 90.
CONCLUSION
Breastfeeding duration was associated with improved educational outcomes at age 16 among children living in England, after controlling for important confounders. However, the effect sizes were modest and may be susceptible to residual confounding. Breastfeeding should continue to be encouraged when possible, as potential improvements in academic achievement constitute only one of its potential benefits. Future studies should adjust for both socioeconomic circumstances (comprehensively) and maternal general intelligence.

Supplemental material
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