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Breast feeding and intergenerational social mobility: what are the mechanisms?

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ABSTRACT

Objective To investigate the association between breast feeding and intergenerational social mobility and the possible mediating role of neurological and stress mechanisms.

Design Secondary analysis of data from the 1958 and the 1970 British Cohort Studies.

Setting Longitudinal study of individuals born in Britain during 1 week in 1958 and 1970.

Participants 17 419 individuals participated in the 1958 cohort and 16 771 in the 1970 cohort. The effect of breast feeding on intergenerational social mobility from age 10/11 to age 33/34 was analysed after multiple imputations to fill in missing data and propensity score matching on a wide range of confounders measured in childhood (1958 cohort N=16 039–16 154; 1970 cohort N=16 255–16 361).

Main outcome measures Own Registrar General's Social Class (RGSC) at 33/34 years adjusted for father's RGSC at 10/11 years, gender and their interaction.

Results Breastfed individuals were more likely to be upwardly mobile (1958 cohort: OR 1.24 95% CI 1.12 to 1.38; 1970 cohort: OR 1.24 95% CI 1.12 to 1.37) and less likely to be downwardly mobile (1958 cohort: OR 0.81 95% CI 0.73 to 0.90; 1970 cohort: OR 0.79 95% CI 0.71 to 0.88). In an ordinal regression model, markers of neurological development (cognitive test scores) and stress (emotional stress scores) accounted for approximately 36% of the relationship between breast feeding and social mobility.

Conclusions Breast feeding increased the odds of upward social mobility and decreased the odds of downward mobility. Consistent with a causal explanation, the findings were robust to matching on a large number of observable variables and effect sizes were alike for two cohorts with different social distributions of breast feeding. The effect was mediated in part through neurological and stress mechanisms.

INTRODUCTION

Breast feeding is known to confer a number of benefits to the developing child. Both the constituents of breast milk and the act of breast feeding have been implicated in the process. Constituents that may offer developmental advantages include long-chain polyunsaturated fatty acids (LCPUFA), immunoglobulins and growth factors. LCPUFAs are essential for neurological development, being needed for metabolic functioning, and dietary intake can boost levels synthesised in the body. Evidence of their benefits for neurological development from trials of LCPUFA added to formula is inconclusive.¹ Nevertheless, many studies find a positive relationship between breast feeding and cognitive outcomes in childhood² and adulthood³ although there are

What is already known on this topic

- Breast feeding confers a number of health and cognitive benefits on the developing child.
- Cognitive and non-cognitive advantages make upward social mobility more likely.

What this study adds

- Breast feeding increased chances of upward social mobility and decreased chances of downward social mobility.
- The effects were explained in part by the indicator of neurological development, cognitive test scores.
- Consistent with a causal explanation, effect sizes were alike across two cohorts with different social distributions of breast feeding and robust to matching on many confounders.

some exceptions.^{4–5} There is also evidence linking breast feeding with temperament,⁶ self-regulation⁷ and a lower risk of adjustment problems,⁸ although effects are weaker. Antibodies such as IgA, present in breast milk, are a source of passively acquired immunity for the infant,⁹ while nerve growth factors and insulin-like growth factors support neuronal and general physiological growth and the maintenance of good health.¹⁰ Observational studies have shown breast feeding to protect children against infections and to promote physical development.^{11–12} A WHO review queried whether the associations are related to the constituents of breast milk or whether breast feeding enhances the bonding between mother and child.¹³ Maternal skin-to-skin contact during nursing was thought to improve bonding, although this has since been questioned.^{14–15} Yet, work with rats showed a greater frequency of licking and grooming during nursing associated with a lower magnitude hypothalamic-pituitary-adrenal (HPA) response to acute stress when full-grown,¹⁶ suggesting skin-to-skin contact could influence development of the infant's stress response through changes in HPA axis functioning. The mechanisms are complex with skin-to-skin contact also influencing maternal stress functioning, in turn affecting the cortisol levels of breast milk.¹⁷

Cognitive and non-cognitive markers of development predict socioeconomic attainment in adulthood.^{18–22} The UK government strategy on



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intergenerational social mobility aims to ensure that everyone has a fair chance of getting a better job than their parents.²³ If breast feeding is related to neurological development and stress mechanisms, and cognition and behaviour in childhood are in turn related to occupational destinations in adulthood, then it is pertinent to ask whether breast feeding has any impact on social mobility. To date, the putative causal role for breast feeding in social mobility has been examined in only one study;²⁴ this study investigated only upward mobility for a sample of adults born before 1940. The authors found a modest effect of breast feeding on upward social mobility but cautioned against the possibility of residual confounding. Direct comparisons between breastfed and non-breastfed respondents in observational studies may be misleading if breastfed individuals differ systematically from those not breast fed.²⁵ Propensity score matching is one method to adjust for selection effects by mimicking some of the characteristics of a randomised controlled trial.²⁶ An alternative method was proposed in a recent study which concluded that causal inference in observational studies can be improved by comparing associations for populations with differing confounding structures.²⁷

This paper therefore adds to what is known in four important ways: (i) by using data from two more recent British birth cohorts with differing social distributions of breast feeding; (ii) taking a propensity score matching approach to more reliably control for factors predictive of breast feeding and of social destinations; (iii) examining whether breast feeding increases the chances of upward social mobility *and* protects against downward social mobility; and (iv) exploring the role of neurological development and stress mechanisms in mediating the relationship between breast feeding and social mobility.

METHODS

The 1958 cohort comprises 17 419 individuals born during 1 week in 1958 in Britain.²⁸ The cohort was followed at ages 7, 11, 16, 23, 33, 42, 46 and 50, with face-to-face interviews with parents, teachers and cohort members; educational assessments; and medical examinations. We use data from birth (response 98.8%) to age 33 (response 70.2%). The British 1970 cohort consists of 16 771 children also born in 1 week of that year.²⁹ The cohort was similarly followed up when the members were aged 5, 10, 16, 26, 30, 34, 38 and 42 years, although the 42-year follow-up has not been released at the time of writing. Data from birth (response 95.9%) to age 34 (response 73.7%) were used.

Main study variables

Mothers were asked when their child was age 7 (1958 cohort) or age 5 (1970 cohort) whether they had breast fed their child. Responses indicate whether the child had never been breast fed, breast fed for less than 4 weeks or breast fed for 4 weeks or more. Parental recall of breast feeding practices after many years has been shown to be reliable and valid.^{30 31}

Father's social class when aged 11 (1958 cohort) or age 10 (1970 cohort) and own social class at age 33 (1958 cohort) or 34 (1970 cohort) were measured using the Registrar General's social class.³² The original six-category schema was reduced to four by combining the top two and bottom two categories, providing larger numbers in the extreme groups. Reordered scales ranged from class IV and V (unskilled/semiskilled manual) to class I and II (professional/managerial). Gender was coded with male as the reference category. Mediating variables were assessed at age 11 (1958 cohort) or 10 (1970 cohort).

Neurological ability was measured by cognitive test scores administered at 11 years (1958 cohort) or 10 years (1970

cohort). Cognition was assessed in the 1958 cohort by the National Foundation for Educational Research (NFER) General Ability Test,³³ administered at school. Two verbal (Word Definitions; Word Similarities) and two non-verbal subscales (Recall of Digits; Matrices) of the British Ability Scales were administered by the 1970 cohort members' teachers.³⁴ Emotional stress scores were assessed by mothers and teachers, also at 10/11 years. For the 1958 cohort, the former completed the Rutter A scale and the latter the Bristol Social Adjustment Guide.³⁵ Mothers of the 1970 cohort members completed the Rutter A scale and teachers the Rutter B scale.^{36 37} All mediators were categorised into quintiles to facilitate comparison between the cohorts and allow for non-linear relationships with social mobility.

Statistical analysis

Some variables had missing values. Multiple imputations were used to create 20 filled-in datasets for each cohort (see online supplementary appendix A for details). Three cases each from the 1958 and 1970 cohorts were excluded because of missing or inconsistent data on gender and three cases were excluded from the 1958 cohort because region of birth was missing since it was not felt that these variables could be imputed beyond chance levels (effective sample N=17 413 (1958 cohort); 16 768 (1970 cohort)). To control for selection bias influencing who was breast fed, we carried out propensity score matching.²⁵ An estimate of the propensity score was obtained by probit regression of a binary treatment indicator (any breast feeding vs none) on baseline covariates (details in online supplementary appendix B). Propensity scores for each respondent in the filled-in datasets were estimated. Postmatching, sample sizes ranged from 16 039 to 16 154 for the 1958 cohort and 16 255 to 16 361 for the 1970 cohort. Substantive models were estimated on the matched samples with coefficients averaged and SEs adjusted according to Rubin's rules.³⁸

Upward mobility was defined as having a higher social class at age 33/34 than father's social class at 10/11 years. Downward mobility was defined similarly as the respondent having a lower class than their father. For upward mobility, respondents whose fathers were in the top category were excluded as they could not move upwards (1958 cohort: mean N=4325; 1970 cohort: mean N=4819) before comparing the upwardly mobile with those who were not (the downwardly mobile or stable). Logistic regression examined the influence of breast feeding on upward social mobility using gender, social class in childhood and a gender by social class interaction as additional covariates since women's social mobility patterns differ from men's.³⁹ Similarly, the odds of downward social mobility if breast fed were estimated after excluding cohort members whose fathers were in the lowest social class group (1958 cohort: mean N=4476; 1970 cohort: mean N=2912).

Since absolute values of the odds of upward and downward mobility were equal in both cohorts (see Results section and table 1), ordinal logistic regression was used to examine the role of the putative mediators. For Model 1, the dependent variable was own social class at age 33/34 conditional on breast feeding, gender, father's social class and the gender by father's class interaction, essentially replicating the earlier models. In Model 2, the indicator of neurological development (cognitive test scores) was added whereas in Model 3, the emotional stress scores were added. Model 4 included both neurological and stress variables. Breast feeding ORs are interpreted as the odds of being one category higher in the social hierarchy, given childhood social class and values on other covariates.

Table 1 ORs and 95% CIs from multivariable logistic regression models of upward and downward social mobility in the 1958 and 1970 cohorts

	1958 cohort		1970 cohort	
	OR	95% CI	OR	95% CI
<i>Upward mobility</i>				
Breast fed	1.24	1.12 to 1.38	1.24	1.12 to 1.37
Female	0.65	0.50 to 0.84	0.80	0.62 to 1.03
RGSC in childhood*				
I/II	(excluded)†		(excluded)†	
IIINM	1.00		1.00	
IIIM	1.04	0.85 to 1.28	1.06	0.88 to 1.27
IV/V	2.84	2.29 to 3.54	3.26	2.56 to 4.11
Gender by RGSC interaction				
Female* I/II	(excluded)†		(excluded)†	
Female* IIINM	1.00		1.00	
Female* IIIM	2.53	1.92 to 3.34	1.98	1.52 to 2.58
Female* IV/V	1.15	0.85 to 1.56	1.03	0.71 to 1.49
N‡	12 429–12 548		11 773–11 900	
<i>Downward mobility</i>				
Breast fed	0.81	0.73 to 0.90	0.79	0.71 to 0.88
Female	1.40	1.22 to 1.60	1.13	0.95 to 1.33
RGSC in childhood§				
I/II	2.49	2.13 to 2.93	2.99	2.54 to 3.54
IIINM	2.08	1.66 to 2.60	2.26	1.79 to 2.85
IIIM	1.00		1.00	
IV/V	(excluded)¶		(excluded)¶	
Gender by RGSC interaction				
Female* I/II	1.12	0.92 to 1.37	1.09	0.88 to 1.35
Female* IIINM	0.54	0.40 to 0.73	0.64	0.47 to 0.89
Female* IIIM	1.00		1.00	
Female* IV/V	(excluded)¶		(excluded)¶	
N‡	12 152–12 276		13 311–13 482	

*Registrar General's social class (RGSC) when child aged 11.

†Cases excluded because upward social mobility is logically impossible for this category.

‡Sample sizes for the 20 filled-in datasets after propensity score matching has been applied and logically impossible cases excluded.

§RGSC when child aged 10.

¶Cases excluded because downward social mobility is logically impossible for this category. IIINM, III non-manual; IIIM, III manual.

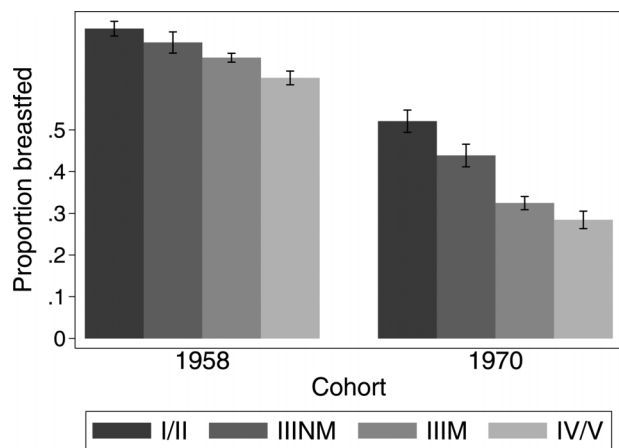


Figure 1 Proportion of children in the 1958 and 1970 cohorts who were breast fed by father's social class at birth (data averaged over 20 filled-in datasets). IIINM, III non-manual; IIIM, III manual.

To compare how breast feeding was socially distributed in the two cohorts, we estimated the Relative Index of Inequality (RII).⁴⁰ Larger RII imply larger breastfeeding differences between professional/managerial and non-skilled social classes. The magnitude of the RII can be attributed to the effect of social class on breast feeding and to inequalities in the distribution of social class itself. Post hoc tests to compare model coefficients between cohorts were carried out using the Stata *suest* (seemingly unrelated estimation) command.

RESULTS

In the 1958 cohort, 68% of mothers breast fed their children compared with 36% in the 1970 cohort. Figure 1 highlights that breast feeding was significantly more socially distributed in the 1970 cohort than the 1958 cohort (RII 1958 cohort 1.94, 95% CI 1.69 to 2.22; RII 1970 cohort 3.62, 95% CI 3.15 to 4.16). The pattern of social mobility also differed between the two cohorts (table 2). Upward social mobility was more likely in the 1970 than the 1958 cohort, but at the same time downward social mobility was less likely in the later born cohort. Total mobility, similar in both cohorts, thus masks differences in upward and downward movements.

Individuals who had been breast fed were more likely to move up the social hierarchy (table 1). The chances of upward mobility were the same for the 1958 cohort (OR 1.24; 95% CI 1.12 to 1.38) and the 1970 cohort (OR 1.24; 95% CI 1.12 to 1.37). Downward social mobility was also related to breastfeeding status: breastfed cohort members were less likely to move down, with ORs of 0.81 and 0.79 for the 1958 and 1970 cohorts, respectively. Post hoc tests confirmed that effects were equivalent in magnitude across cohorts and for upward and downward mobility.

The mediators were all related to breast feeding and to social mobility in both cohorts (table 3) with the exception of the maternal reported emotional stress score which had inconsistent associations by cohort. Nevertheless, for completeness, the score was included in the mediation models reported in table 4. Excluding this variable did not alter the findings substantively.

In table 4, Model 1 is a respecification of the upward and downward models that assumes the effects of breast feeding on upward and downward social mobility are equal in magnitude and opposite in direction, as confirmed by the post hoc tests. Model 2 shows that there is some attenuation of the estimate for breast feeding after controlling for cognitive test scores suggesting that the effect of breast feeding effect may operate through neurological development. The role for stress mechanisms is more tenuous with very little attenuation by the emotional and physical stress scores (Model 3). Finally in Model 4, all the proposed mediators are entered simultaneously, confirming that breast feeding is mainly mediated via neurological development. Approximately 36% of the effect of breast feeding is accounted for by the mediators.

DISCUSSION

This is the first large population-based study to investigate the relationship between, and potential mechanisms underlying, breast feeding and intergenerational social mobility. We employed two analytic strategies to strengthen a causal interpretation: propensity score matching and the comparison of associations between cohorts with differing distributions of breast feeding by social class.^{25 27} The results show that breast feeding was consistently associated with an increased chance of upward social mobility and a decreased chance of downward mobility. The same effect size was observed in two cohorts born 12 years

Table 2 Intergenerational social mobility* in the 1958 and 1970 cohort studies

Social class in childhood	N	Social mobility into adulthood		
		Upward	Stable	Downward
1958 cohort				
I/II	3876 (3764 to 3989)	NA	0.55 (0.53 to 0.57)	0.45 (0.43 to 0.47)
IIINM	1576 (1488 to 1665)	0.41 (0.38 to 0.44)	0.26 (0.24 to 0.29)	0.32 (0.30 to 0.35)
IIIM	7306 (7163 to 7448)	0.52 (0.51 to 0.54)	0.23 (0.22 to 0.24)	0.24 (0.23 to 0.26)
IV/V	4010 (3892 to 4127)	0.67 (0.65 to 0.69)	0.33 (0.31 to 0.35)	NA
N		7160 (7005 to 7314)	5559 (5417 to 5701)	4050 (3925 to 4174)
1970 cohort				
I/II	4819 (4688 to 4950)	NA	0.60 (0.58 to 0.62)	0.40 (0.38 to 0.42)
IIINM	1497 (1414 to 1581)	0.48 (0.45 to 0.51)	0.23 (0.20 to 0.25)	0.29 (0.26 to 0.32)
IIIM	7540 (7381 to 7698)	0.57 (0.56 to 0.58)	0.24 (0.23 to 0.25)	0.19 (0.17 to 0.20)
IV/V	2912 (2793 to 3031)	0.75 (0.72 to 0.77)	0.25 (0.22 to 0.28)	NA
N		7192 (7033 to 7351)	5785 (5619 to 5952)	3790 (3647 to 3934)

*Proportion mobile based on Registrar General's social class of father at age 11 (1958 cohort) or age 10 (1970 cohort) and own Registrar General's social class at age 33 (1958 cohort) or age 34 (1970 cohort). Data averaged over 20 filled-in datasets with sample size 17 413 (1958 cohort) and 16 768 (1970 cohort). IIINM, III non-manual; IIIM, III manual.

apart who had different social patterning of breast feeding and different patterns of intergenerational social class mobility.

Mediation models suggested that breast feeding advanced neurological development resulting in improved cognitive performance which in turn supported upward social mobility and protected against downward social mobility. Children who seemed to be under greater stress were less likely to be upwardly mobile and more likely to be downwardly mobile, and breastfed children showed fewer signs of emotional stress. However, this pathway was less important than the neurological one.

A major strength of the study is that the data are representative of the British population. Large-sample representative longitudinal data from birth to mid-adulthood are rare outside the UK. Since both cohorts had their origins in studies of perinatal mortality, data collection included a broad range of information on the circumstances surrounding birth and allowing inclusion of a large number of potential confounding factors known to affect breastfeeding initiation and maintenance in the propensity score models. Matching of breastfed and formula fed children attenuated the breastfeeding effect compared with standard ordinary least squares (OLS) estimates (data not shown), consistent with assumptions that confounding could bias results. While one can never rule out the possibility that residual confounding is still present, the consistency of our results across cohorts lends support to a causal mechanism. The study also benefited from the regular interviewing of cohort members and their

families, allowing for the missing at random assumption of the imputation models to be supported using auxiliary variables from other data collection sweeps, although we cannot exclude the possibility that data were missing not at random.

A limitation is that breast feeding was measured retrospectively according to maternal report. This may result in some misclassification. It was also not possible to derive a more fine-grained measure of breastfeeding duration together with the propensity score matching approach. Supplementary analyses (not shown) indicated that effect sizes were larger if children breast fed for less than 4 weeks were compared with children breast fed for 4 or more weeks and greater still if children who were not breast fed were compared with those breast fed for 4 or more weeks, suggesting a dose-response effect or possibly a reduction in effect size due to misclassification. A further limitation is the lack of clinical measures, relying on maternal and teacher reports of emotional stress which could be prone to response bias. However, using multi-informant reports can counteract this problem.⁴¹ Finally, while the formal comparison of the RIIs measuring social class differences in breast feeding in each of the two cohorts confirmed a statistically significant difference, this was not as dramatic a contrast as in the Brion *et al* paper.²⁷

To our knowledge, only one study has directly assessed the effect of breast feeding on upward social mobility.²⁴ In that study, only 44% of eligible respondents had data on social class in both childhood and adulthood and on breast feeding in

Table 3 Mean scores* with 95% CIs in parentheses for the childhood mediators by breastfeeding status

	1958 cohort		1970 cohort	
	Not breast fed	Breast fed	Not breast fed	Breast fed
Cognitive test score†	98.06 (97.63 to 98.49)	101.13 (100.83 to 101.42)	98.36 (98.05 to 98.67)	102.11 (101.64 to 102.57)
Maternal reported emotional stress score‡	-0.013 (-0.043 to 0.018)	0.002 (-0.020 to 0.023)	0.026 (0.006 to 0.045)	-0.030 (-0.059 to -0.001)
Teacher reported emotional stress score‡	0.058 (0.028 to 0.088)	-0.039 (-0.059 to -0.020)	0.034 (0.013 to 0.055)	-0.048 (-0.079 to -0.017)
	Upwardly mobile	Downwardly mobile	Upwardly mobile	Downwardly mobile
Cognitive test score†	101.26 (99.80 to 100.71)	97.43 (96.83 to 98.02)	99.78 (99.39 to 100.17)	96.74 (96.16 to 97.33)
Maternal reported emotional stress score‡	-0.048 (-0.075 to -0.021)	0.066 (0.029 to 0.104)	0.032 (0.004 to 0.060)	0.032 (-0.007 to 0.071)
Teacher reported emotional stress score‡	-0.116 (-0.142 to -0.091)	0.141 (0.101 to 0.180)	-0.028 (-0.063 to 0.006)	0.126 (0.076 to 0.176)

*Data averaged over 20 filled-in datasets after propensity score matching has been applied with sample sizes 16 039-16 154 (1958 cohort) and 16 255-16 361 (1970 cohort).

†Scores standardised to have mean 100, SD 15.

‡Scores standardised to have mean 0, SD 1.

infancy ($N \approx 1400$). The authors acknowledged that they were neither able to investigate causal pathways nor to rule out the possibility of residual confounding. Interestingly though, their estimates of the causal effect of breast feeding were very similar to ours. Studies that have estimated effects separately for low birth weight and preterm infants have tended to show that shorter term benefits are greater for these children than healthy full-term children.^{2 42} We speculate that the long-term gains from breast feeding for these more vulnerable children may be greater too.

It is difficult to disentangle the independent role for the nutrient content of breast milk versus the role of skin-to-skin contact. While our results show a stronger mediating pathway through neurological development than through stress response mechanisms, studies of supplementation of formula milk suggest that LCPUFAs alone may not improve cognitive development.^{1 43 44} However, other bioactive constituents of breast milk may also be important. Skin-to-skin contact has been related to improved mother-child bonding and cognitive functioning.^{45 46} Perhaps the combination of physical contact and the most appropriate nutrients required for growth and brain development is implicated in the better neurocognitive and adult outcomes of breastfed infants.⁴⁷ This might suggest that mothers who do not breast feed could aid their child's development by mimicking the close skin-to-skin contact that breast-feeding mothers naturally have with their infant during feeding and selecting brands of formula that contain LCPUFA. The UNICEF Baby Friendly Initiative aims to increase breastfeeding initiation rates throughout the world. The 2010 Infant Feeding Survey showed that in the UK, only a third of mothers who start to breast feed still do so exclusively at 6 weeks implying that extending the initiative to policies that sustain breast feeding is also recommended.

More research is needed on the association between breast feeding and child cognitive and socio-emotional development if we are to elucidate the causal mechanisms through which breast feeding can have lifelong implications for health and well-being. Identifying subgroups that might benefit most from breast feeding would enable interventions to be targeted more effectively. This necessitates large studies collecting detailed infant feeding data, including duration of partial and exclusive breast feeding, breastfeeding schedules, mode of receiving breast milk, and type of formula together with parental cognitive tests.

Table 4 Relationship of breast feeding with social class in adulthood (ORs and 95% CIs) from ordinal regression social mobility models

	1958 cohort		1970 cohort	
	OR	95% CI	OR	95% CI
Model 1*	1.24	1.13 to 1.36	1.29	1.19 to 1.40
Model 2†	1.14	1.04 to 1.25	1.19	1.09 to 1.29
Model 3‡	1.22	1.12 to 1.33	1.28	1.18 to 1.38
Model 4§	1.14	1.04 to 1.25	1.19	1.09 to 1.29
N¶	16 039–16 154		16 255–16 361	

*Controlling for gender, social class of father and their interaction.

†Model 1 plus cognitive test score quintiles.

‡Model 1 plus emotional stress score quintiles (mother and teacher reported).

§Model 1 plus cognitive test score quintiles and emotional stress score quintiles (mother and teacher reported).

¶Sample sizes for the 20 filled-in datasets after propensity score matching applied to each dataset.

In conclusion, our study adds to evidence on the health benefits of breast feeding by showing that there may be lifelong social benefits. Applying propensity score matching and comparing across cohorts with different social distributions of breast feeding goes some way towards overcoming the limitations of observational data, giving us more confidence in a causal interpretation of the findings.

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Contributors All authors contributed to the design of the study. NC extracted and cleaned the data. AS and MI performed the data analysis. All authors interpreted the results. AS drafted the paper. MB, MI and YK reviewed and edited the paper. AS is the guarantor. All authors had full access to all of the data (including statistical reports and tables) in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors conducted this work independently of the funders of the cohort studies.

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Data sharing statement The datasets are available from the UK Data Archive. Further information about the studies and data can be found online (<http://www.cls.ioe.ac.uk/>).

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Appendix A.

We imputed missing data using the multivariate imputation by chained equations method implemented in STATA 12. This uses a missing at random (MAR) assumption. Supplementary variables were used in the imputation models. These included the same variables collected at other waves and variables measuring other constructs that were highly correlated with the main study variables. Table A1 gives the proportion of missingness for all variables used in either the propensity score model or the substantive mobility models.

Table A1. Missing data in the two cohorts

1958 cohort	N	% missing	1970 cohort	N	% missing
Breastfed	14625	16.01	Breastfed	12610	24.80
Region	17413	0.00	Region	16768	0.00
Mother's age	17398	0.09	Mother's age	16668	0.60
Marital status	17402	0.06	Father's age	11938	28.80
Mother's education	17350	0.36	Marital status	16768	0.00
Father's social class at birth	16455	5.50	Mother's education	16628	0.83
Overcrowding	16917	2.85	Father's education	11946	28.76
Number of maternal siblings	17232	1.04	Father's social class at birth	15396	8.18
Mother's age at first birth	16909	2.89	Mother's social class at birth	10308	38.53
Parity	17409	0.02	Mother's age at first birth	16569	1.19
Number of premature births	17285	0.74	Smoking in pregnancy	16685	0.49
Smoking prior to pregnancy	17346	0.38	Drinking in pregnancy	16768	0.00
Smoking after pregnancy	17187	1.30	Date of first antenatal visit	16486	1.68
Date of first antenatal visit	16961	2.60	Number of antenatal visits	16089	4.05
Number of antenatal visits	17137	1.59	Attended mothercraft classes	16648	0.72
Gestation	15569	10.59	Attended labour preparation classes	16632	0.81
Mother's height	16703	4.08	Mother ill during pregnancy	16767	0.01
Haemoglobin count	16867	3.14	Gestation	13320	20.56
Hours worked during pregnancy	5479	68.54	Mother's height	16602	0.99
Number cooks for in family	17134	1.60	Haemoglobin count	12092	27.89
Mode of delivery	17407	0.03	Fetal distress	16173	3.55
Fetal distress	17406	0.04	Duration of labour	16622	0.87
Duration of labour	16994	2.41	Baby's weight	16751	0.10
Baby's weight	16780	3.64	Multiple birth	16768	0.00
Birth abnormalities	17401	0.07	Father's social class age 10	11386	32.10
Father's social class age 11	12889	25.98	Cognitive test score	11511	31.35
Cognitive test score	14132	18.84	One hand catches	12002	28.42
Left hand catches	12647	27.37	Left hand matches sorted	11978	28.57
Left hand matches sorted	12753	26.76	Left foot stand	11972	28.60
Left hand squares ticked	12778	26.62	Both hand catches	11852	29.32
Right hand catches	12643	27.39	Right hand matches sorted	11982	28.54
Right hand matches sorted	12757	26.74	Right foot stand	11955	28.70

Right hand squares ticked	12778	26.62	Mother reported emotional stress	12592	24.90
Mother reported emotional stress	13787	20.82	Teacher reported emotional stress	11728	30.06
Teacher reported emotional stress	14157	18.70	Nightmares	14875	11.29
Nightmares	13643	21.65	Sleep walks	14875	11.29
Sleep walks	13731	21.15	Wet by day	12036	28.22
Wet by day	13715	21.24	Wet at night	12551	25.15
Wet at night	13792	20.79	Soils	12058	28.09
Soils	13764	20.96	Own social class at 34 years	7352	56.15
Own social class at 33 years	10582	39.23			

Appendix B. Propensity score matching

Baseline covariates include indicators of socio-demographics (region, parents' ages, marital status, parental education, parental social class, overcrowding, maternal siblings) maternal fertility history (age at first birth, parity, previous premature children), pregnancy characteristics (smoking prior to/ during/ after pregnancy, drinking in pregnancy, first antenatal visit, number of antenatal visits, mothercraft and labour classes, gestation, maternal height, mother's haemoglobin, maternal illness, hours worked, number cooks for) and birth outcomes (multiple birth, type of delivery, distress, duration of labour, birth weight, any abnormalities). Not all variables were available for both cohorts and so the matching procedure was carried out separately for each cohort. Baseline covariates in common were region, mother's age, marital status, mother's education, parental social class, age at first birth, parity, mother's haemoglobin, gestation, illness in pregnancy, first antenatal visit, number of antenatal visits, type of delivery, signs of fetal distress, birth weight, labour and any abnormalities.

The propensity score was used as the basis for matching the breastfed and formula fed cohort members. We carried out a 1:3 propensity score matching procedure with a nearest neighbour matching algorithm within callipers (width of propensity score intervals) of width 0.0002 standard deviations of the propensity score, dropping 2% of the treatment observations where the pscore density of the control observations is the lowest.

All the variables in the propensity score models had a bivariate association with breastfeeding. In multivariate models on the 1958 cohort, mothers were more likely to breastfeed if they were older, taller, more educated, in a more advantaged social class, did not smoke before the pregnancy, and had a full-term baby. They were less likely to breastfeed if they were ill in pregnancy, attended the first antenatal clinic earlier, had a low haemoglobin count, previous premature babies, lived in overcrowded accommodation, and gave birth to a low birth weight baby with health problems. In the 1970 cohort, taller older more educated and more socially advantaged mothers of full-term singleton children were more likely to breastfeed. Mothers who smoked, were ill in pregnancy, who did not attend mothercraft or labour preparation classes were less likely to breastfeed.

Standardised differences are used to examine the balance of the matched groups of breastfed and formula fed groups. Table B1 gives matching diagnostics for each of the 20 filled-in datasets averaged over all variables. It shows evidence of significant differences in the distribution of the propensity score matching variables for breastfed and formula-fed children before matching which disappeared after matching. Figure B1 complements Table B1 by giving diagnostics for each

variable averaged over the 20 filled-in datasets. This perspective also confirmed that differences in the matching variables were eliminated after matching.

Table B1 Propensity score matching diagnostics averaged over all variables

Sample	Before matching					After matching				
	Mean absolute standardised bias ^	Median absolute standardised bias	Pseudo R ² *	LRT χ^2 +	LRT p-value	Mean absolute standardised bias^	Median absolute standardised bias	Pseudo R ² *	LRT χ^2 +	LRT p-value
1958 cohort										
1	7.64	6.50	0.051	1204	<0.0005	0.78	0.62	0.001	22	1.00
2	7.30	6.21	0.049	1160	<0.0005	0.79	0.73	0.001	19	1.00
3	7.38	5.96	0.048	1139	<0.0005	0.65	0.64	0.001	21	1.00
4	7.23	6.15	0.048	1132	<0.0005	0.69	0.61	0.001	19	1.00
5	7.30	6.17	0.048	1148	<0.0005	0.88	0.70	0.002	32	1.00
6	7.49	6.45	0.050	1190	<0.0005	0.81	0.69	0.001	27	1.00
7	7.48	5.88	0.050	1182	<0.0005	0.80	0.78	0.001	24	1.00
8	7.13	5.86	0.045	1067	<0.0005	0.70	0.63	0.001	24	1.00
9	7.69	6.55	0.050	1191	<0.0005	0.67	0.62	0.001	20	1.00
10	7.48	5.79	0.049	1154	<0.0005	0.89	0.74	0.001	29	1.00
11	7.36	5.27	0.047	1123	<0.0005	0.78	0.69	0.001	23	1.00
12	7.43	5.82	0.049	1173	<0.0005	0.65	0.43	0.001	18	1.00
13	7.28	6.10	0.049	1176	<0.0005	0.71	0.58	0.001	23	1.00
14	7.37	6.15	0.047	1122	<0.0005	0.79	0.61	0.001	27	1.00
15	7.41	5.74	0.051	1213	<0.0005	0.75	0.67	0.001	20	1.00
16	7.33	6.35	0.017	1119	<0.0005	0.70	0.61	0.001	23	1.00
17	7.50	6.03	0.050	1187	<0.0005	0.78	0.68	0.001	22	1.00
18	7.12	5.86	0.046	1087	<0.0005	0.63	0.60	0.001	15	1.00
19	7.38	5.88	0.047	1106	<0.0005	0.77	0.68	0.001	24	1.00
20	7.26	5.23	0.048	1136	<0.0005	0.73	0.59	0.001	23	1.00
1970 cohort										
1	14.22	11.90	0.095	1624	<0.0005	0.95	0.76	0.001	9	1.00
2	14.43	11.65	0.099	1680	<0.0005	0.95	0.69	0.001	13	1.00
3	14.39	12.63	0.100	1706	<0.0005	0.98	0.82	0.001	11	1.00
4	14.15	11.92	0.097	1655	<0.0005	0.94	0.70	0.001	12	1.00
5	13.71	11.74	0.091	1557	<0.0005	1.01	0.94	0.001	13	1.00

6	14.11	11.80	0.096	1631	<0.0005	0.96	0.92	0.001	11	1.00
7	14.41	12.80	0.099	1686	<0.0005	0.94	0.79	0.001	13	1.00
8	14.12	11.200	0.099	1686	<0.0005	1.11	1.05	0.001	14	1.00
9	14.05	11.91	0.095	1623	<0.0005	1.03	0.85	0.001	13	1.00
10	13.99	11.32	0.097	1663	<0.0005	1.08	1.02	0.001	10	1.00
11	14.01	11.14	0.097	1632	<0.0005	0.88	0.64	0.001	9	1.00
12	14.41	11.70	0.100	1711	<0.0005	1.12	1.07	0.002	14	1.00
13	14.00	12.22	0.093	1583	<0.0005	0.94	0.81	0.001	11	1.00
14	14.07	7.38	0.095	1627	<0.0005	0.96	0.70	0.001	12	1.00
15	14.38	12.49	0.099	1674	<0.0005	0.86	0.65	0.001	9	1.00
16	13.94	11.07	0.095	1619	<0.0005	0.82	0.61	0.001	10	1.00
17	14.28	11.60	0.097	1651	<0.0005	0.98	0.85	0.001	13	1.00
18	14.31	12.75	0.097	1643	<0.0005	1.20	1.08	0.002	15	1.00
19	14.59	11.43	0.101	1720	<0.0005	0.71	0.57	0.001	8	1.00
20	14.12	11.99	0.099	1694	<0.0005	1.16	0.98	0.002	15	1.00

* Pseudo R2 is from a probit of treatment status on all the variables in the propensity score model before matching and on the matched samples

+ Likelihood-ratio test of the joint insignificance of all the independent variables in the propensity score model before and after matching

^ Standardised bias is the difference of the sample means in the breastfed and non-breastfed (before or after matching) sub-samples as a percentage of the square root of the average of the sample variances in the breastfed and non-breastfed groups

Figure B1. Percentage standardized differences for baseline covariates comparing breastfed with formula fed children in the original and the matched samples from the 1958 and 1970 cohorts.

