Effect of breastfeeding on cognitive performance in a British birth cohort

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تأثير الرضاعة الطبيعية من الثدي على الأداء المعرفي لدى أتراب من بريطانيا

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الخلاصـة: تستقصي دراسة الأتراب التي نحن بصددها تأثير التغذية في مراحل العمر الباكرة على الأداء في المراحل المتأخرة من خلال نقاط تحدد معالم النمو، ومن خلال اختبارات معرفية. فقام الباحثون بتنفيذ نموذج لمعادلة بنيوية (هيكلية) حول معلومات المتابعة المستمدّة من أتراب يشتركون بالولادة على المستوى الوطني ويتكونون من 5362 طفلاً ممن ولدوا في بريطانيا في الأسبوع الأول من عام 1946. وتبين للباحثين أن الأطفال الذين تلقوا رضاعة طبيعية من الثدي لفترة أطول ظهرت عليهم نقاط تحدد معالم النمو في وقت أبكر مما لدى غيرهم. وبعد أن قام الباحثون بالتعديل (التصحيح) وفق الجنس، ووفق المجموعات الاجتماعية ووفق النقاط التي تحدد المعالم، اتضح لهم أن هؤلاء الأطفال قد حازوا على أحراز (درجات) أعلى من غيرهم في الاختبارات الشفهية. كما أوضحت تحليلات الطرق المستخدمة أن الرضاعة الطبيعية من الثدي قد تؤثر على الحياة حتى أثناء فترة البلوغ، كما اتضح أن سلسلة عوامل الطرق المتبعة بدءاً من الرضاعة الطبيعية من الثدي مروراً بنقاط تحدد معالم النمو في المراحل العمرية الباكرة، وبالدرجات المعرفية المحرزة في أعمار تتراوح بين 8-15 عاماً، وباختبارات القراءة في عمر 26 عاماً وباختّبار الذاكرة وبالاختبارات البصرية في عمر 43 عاماً، كلها ذات أهمية إحصائية لدى الإناث وليس لدى الذكور.

ABSTRACT This cohort study investigated the effect of early life nutrition on later performance in developmental milestones and cognitive tests. Structural equation modelling was carried out on follow-up data from a national birth cohort of 5362 children born in 1 week of 1946 in Britain. Children who were breastfed longer showed earlier developmental milestones. After adjusting for sex, social group and milestones, those children scored higher in verbal tests. Path analysis showed that breastfeeding may have an effect even into adult life. The chain of path coefficients from breastfeeding to developmental milestones at early ages, to cognitive scores at ages 8–15 years, to reading tests at age 26 years and to memory and visual tests at age 43 years were significant in females but not in males.

Effets de l'allaitement sur les performances cognitives dans une cohorte de naissance britannique

RÉSUMÉ Cette étude de cohorte a analysé les effets de l'alimentation du nouveau-né sur les performances lors des principales étapes du développement et aux tests cognitifs. Une modélisation par équations structurelles a été réalisée sur les données de suivi d'une cohorte de naissance nationale de 5 362 enfants nés la même semaine en 1946, en Grande-Bretagne. Les enfants allaités plus longtemps ont franchi plus rapidement les étapes du développement. Après ajustement des données relatives au sexe, au groupe social et aux étapes du développement, ceux-ci ont également obtenu de meilleurs résultats aux tests verbaux. L'analyse des pistes causales a fait apparaître que l'allaitement maternel pouvait même avoir des effets dans la vie adulte. Les coefficients de piste (allaitement maternel, étapes du développement de la petite enfance, résultats cognitifs entre 8 et 15 ans, tests de lecture à 26 ans, et tests de mémoire et tests visuels à 43 ans) étaient significatifs chez les femmes, mais pas chez les hommes.

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Introduction

Health status at any age in the life span of an individual depends on an accumulation of life events and experiences, especially early life events. There is considerable evidence that good nutrition in early life has a positive effect on the development of the brain and cognitive performance [*1,2*]. During 2 critical periods in development of the central nervous system prenatal and postnatal, nutrition may affect fetal growth [*2*], developmental milestones [*3,4*] and physical growth [*5,6*] of the child. It has been hypothesized that breastfeeding affects cognitive performance in later life, independently or via earlier developmental milestones and better physical growth [*7,8*]. The psychosocial effects of breastfeeding and its protective role against illness have also been reported [*9*].

Undernutrition during fetal growth may cause low birth weight, which may result in poorer performance on tests of cognitive function in later life [*10–12*]. Postnatal nutrition, in particular breastfeeding, may manage not only the development of the brain [*13*], but also affect the child's developmental milestones. For example, one study showed that children who were breastfed talked and walked earlier than those who were never breastfed [*14*]. Children who were breastfed score higher on cognitive performance than those who never breastfed, and this has been found to be true between ages 8 and 15 years [*7,8,10,15*].

In view the previous research in this area, one aim of this study was to investigate whether breastfeeding was related to cognitive function in adulthood. Since the rate of increase in cognitive performance is influenced by factors such as intrauterine growth, illness, socioeconomic status, home conditions, parental characteristics and type of education, we also investigated whether or not these factors are associated with verbal and memory tests over time. Some longitudinal studies have been carried out to examine the direct and indirect effects of nutrition and other influences on later life development. Therefore, another aim of the study was to examine the effect of the duration of breastfeeding on neurological and cognitive tests assessed at ages 2, 8, 11, 15, 26 and 43 years. Finally, we planned to develop path diagram models illustrating the mechanisms of the long-term effect of breastfeeding on later life performance.

Methods

This was a longitudinal cohort study using follow-up data from the 1946 British birth cohort. The cohort originally included all single, legitimate births in England, Wales and Scotland in 1 week (3–9 March) in 1946. A sample of 13 687 out of 16 695 (82%) of the infants was selected, then a sub-sample of these was selected (*n* = 5362), stratified by father's social class to follow up the infants [*16*].

Data collection included a wide range of social, family and health factors, and was undertaken frequently in childhood (at ages 2, 4 and 6 years) and later at longer intervals (ages 8, 11, 15, 26 and 43 years). Data were collected under the management of the United Kingdom Medical Research Council by health visitors, school nurses, school doctors, teachers, postal contacts, interviewers and research nurses. Approved health visitors visited the cohort members at home when they were aged 2, 4 and 6 years, and filled specially designed questionnaires to collect data on developmental milestones and anthropometric variables. At school ages, health and educational progress data were collected by school nurses, school doctors and teachers and recorded in questionnaires. At the later ages, qualified interviewers and research nurses were used to collect data at home.

Measurements in this study were sex, socioeconomic status, duration of breastfeeding in months (ascertained from mothers by health visitors when the cohort members were aged 2 years), neurological tests (age of walking, talking, standing and age of appearance of the first tooth), physical growth (weight and height at ages 4 and 6 years). These data were collected at home. Cognitive tests at 8 years (sentence completion, reading and vocabulary tests), cognitive tests at 11 years (verbal, reading and vocabulary tests), cognitive tests at 15 years (verbal, reading and vocabulary tests) were collected at school. Reading test at 26 years, visual and memory tests at age 43 years (number of correctly remembered words, number of hits in picking a letter from a grid of letters) were collected at health centres by appointment. All developmental tests after age 8 years used self-completed questionnaires and did not require specialists to collect the data.

The following additional data were taken into consideration in the multivariate analysis: birth weight, childhood illness, home conditions, parents' age and education, child's behavioural scores, parents' interest in the child's development and school type [*16*]. Parents' interest in child's education at primary and secondary schools was scored using data on parent's visits to the school, discussions with the child's teacher and participation in the parent/teacher association. Scores ranged from 0 to 50 and from low interest to high interest. Other adult factors used in the study were: current level of education, ownership of accommodation, current social class and number of accidents. All cognitive test scores were normalized to a mean of 100 and a standard deviation (SD) of 10. Although there have been losses in the sample over time, it has been shown that the sample cohort is still representative of almost all people born in Britain in 1946 [16].

The statistical methods used in the analysis were confirmatory factor analysis and path analysis, which are special cases of structural equation modelling [17]. The former method was used to reduce the observed correlations into fewer constructs. The latter method was used to develop path diagrams, which were hypothesized to display the mechanism of the effect of breastfeeding on later life performance.

The statistical analysis was carried out using *LISREL*, version 8.12 [17].

Results

Effect of breastfeeding on reading and memory tests

Table 1 includes the mean scores of reading and memory tests by frequency of breastfeeding, and shows an increase in cognitive performance over time by breastfeeding subgroup. Mean scores on reading tests at age 8 years, 11 years and 15 years were higher in children who were breastfed 4 months or longer. Although the mean scores of reading test at age 26 years and memory test at age 43 years were not influenced by breastfeeding directly, the indirect effect of breastfeeding mediated by developmental milestones and previous test scores was significant (see later analysis).

Effect of birth weight on developmental milestones

Birth weight, which reflects the quality of fetal growth, had an inverse relationship with developmental milestones. As Table 2 shows, children who had birth weight ≤ 2500 g has slightly later milestones compared with children with birth weight > 2500 g. For example, children with birth weight ≤ 2500 g walked at a mean age of 14.2 months (SD 2.8), whereas children in the 2501–3499 g and ≥ 3500 g birth weight groups walked at ages 13.6 months (SD 2.5) and 13.4 months (SD 2.3) respectively. One-way analysis of variance showed that the difference in age of walking among the 3 birth weight groups was significant. Furthermore, path analysis showed that after adjustment for confounders, 1 unit increase in the standardized score of birth weight decreased the standardized score of milestones by –0.14 [standard error (SE) 0.02] for females and by –0.07 (SE 0.02) for males.

Effect of breastfeeding on cognitive performance in later life

After adjustment for confounders as described in the Methods, the direct, indirect and total effects of breastfeeding on cognitive performance in later life were estimated (Table 3). Path coefficients showed that longer duration of breastfeeding was associated with earlier developmental milestones in both boys and girls. Interestingly, the girls' developmental milestones were significantly influenced by nutrition in early life [standardized path coefficient (*r*) = –0.12 (SE 0.02)] whereas in boys the effects were not statistically significant [*r* = –0.01 (SE 0.02)].

An increased duration in breastfeeding was associated directly with verbal ability of males between ages 8 and 15 years [*r* = 0.08 (SE 0.014)] and indirectly with verbal ability of females by [*r* = 0.01 (SE 0.002)]. Since the direct link between breastfeeding and verbal ability between ages 8 and 15 years showed an unexpected negative coefficient for females, this direct path was deleted from the female model and attention was paid to the indirect effect. Longer breastfeeding increased girls' cognitive scores indirectly, mediated by developmental milestones, whereas breastfeeding had a direct effect on boys' cognitive scores (Table 3).

Breastfeeding did not show any direct effect on the reading scores at age 26 years for either males or females. However, men scored higher on the reading test at 26 years indirectly, mediated through the developmental milestones and past verbal scores. That is to say, the initial significant effect of breastfeeding on the men's milestones and on the school attainment tests came together and were associated with higher reading scores at age 26 years. No direct

Table 1 Mean scores of reading and memory tests and cognitive tests at different ages by frequency of breastfeeding

Variable	Frequency of breastfeeding						*P*-value[a]
	Never		1–3 months		4+ months		
	No.	Mean (SD) score	No.	Mean (SD) score	No.	Mean (SD) score	
Cognitive tests at age 8 years	903	100.9 (14.4)	1139	101.6 (14.3)	1843	102.6 (14.1)	0.008
Cognitive tests at age 11 years	877	101.2 (13.7)	1110	101.8 (13.8)	1769	102.8 (13.4)	0.008
Cognitive tests at age 15 years	837	101.6 (13.8)	1080	102.1 (12.9)	1709	102.8 (13.3)	0.013
Reading tests at age 26 years	717	102.2 (13.5)	902	102.2 (13.2)	1495	102.1 (13.2)	0.910
Visual and memory tests at age 43 years	644	6.07 (2.02)	828	6.08 (1.81)	1369	6.23 (1.93)	0.870

Numbers do not always add up to 5362 as missing values were excluded.
[a]After adjustment for sex, social group and previous reading scores.
SD = standard deviation.

Table 2 Mean age of developmental milestones by birth weight

Milestone	Birth weight						*P*-value
	≤ 2500 g		2501–3499 g		≥ 3500 g		
	No.	Mean (SD) age (months)	No.	Mean (SD) age (months)	No.	Mean (SD) age (months)	
Sitting	232	7.0 (1.7)	2383	6.6 (1.5)	2042	6.4 (1.4)	< 0.001
Standing	224	12.1 (2.8)	2376	11.4 (2.2)	2033	11.2 (2.1)	< 0.001
Walking	223	14.2 (2.8)	2360	13.6 (2.5)	2046	13.4 (2.3)	< 0.001
Talking	216	14.9 (4.4)	2257	14.2 (4.2)	1941	14.4 (4.2)	0.03

Numbers do not always add up to 5362 as missing values were excluded.
SD = standard deviation.

effects were found for the reading test in females at age 26 years.

At age 43 years, the construct scores were based on visual and memory tests. Path coefficients for this age suggested that women who were breastfed longer scored higher than those who were never breastfed. However, no direct or indirect effects were found for men (Table 3).

Path diagrams

In order to illustrate how breastfeeding in early life may improve developmental milestones and cognitive performance in later life, hypothesized path diagrams were fitted to the cohort data and the results are depicted in Figures 1 and 2 for females and males, respectively. Each figure contains links from early life to later life, and on each link the path coefficient with its standard error is shown. The thick black solid links indicate the most plausible and significant paths from early to later life. Significant path coefficients are superscripted by an asterisk. Breastfeeding was associated with early milestones, which in turn increased cognitive scores of ages 8 and 15 years, followed by an increase in reading scores at age 26 years, and which in turn led to an increase in cognitive scores at age 43 years. The path diagrams fitted to the data were statistically and chronologically acceptable, since both the unadjusted and adjusted goodness-of-fit indices were close to 1.0, which indicated a plausible model for the effects of breastfeeding over time.

Discussion

When assessing nutritional influences on developmental milestone scores, breastfeeding was statistically significantly associated with earlier milestones in females but not in males. Therefore, increases in the duration of breastfeeding appear to bring forward the age of milestones such as age of talking, walking, etc. However, this finding does not agree with Florey et al. [*3*] and Smith and Gerber's findings [*14*]. A controversy in these studies is that they did not use multivariate analysis and they reported their results only based on simple correlation coefficients or simple regression models. Smith's study had only 29 subjects. Also, both of them failed to examine any indirect effect of breastfeeding. Another group of studies supported the relationship between breastfeeding and milestones found in our study in biological terms. For example, Farquharson et al. [*18*] and Morley and Lucas [*19*] suggested a biological theory that long-chain polyunsaturated fatty acids (docosahexaenoic or DHA) found in human milk, which are not found in formula milks, are critical nutrients for neurodevelopment and cognitive performance. Indeed, at birth the infant probably has all of the approximately 100 billion nerve cells it is going to have its entire life. It is believed that at birth and in early infancy the network of these neurons is not impoverished and the interconnection of the neurons seems to be managed by human nutrition and specifically by breastfeeding [*20*].

We found that breastfeeding was associated with improved cognitive performance at school ages. Increased duration of breastfeeding may directly improve the verbal ability of males between ages 8 and 15 years and indirectly in females. This finding is in close agreement with several studies which provide evidence that breastfeeding is the strongest determinant of subsequent cognitive performance [*7,12,21*]. Those studies are of particular interest because there was a dose–response relationship between the proportion of mother's milk in the diet and subsequent test scores. Therefore, the coefficients found in our study might be considered as dose–response effects of breastfeeding on cognitive tests at age 8–15 years. This finding supports the idea that birth weight and breastfeeding together play an important role in programming subsequent cognitive function [*2,15*]. Such a long-term effect of breastfeeding on cognitive function at age 15 years might be because the major growth activity in the human brain is not completed until 2 years of age, and the immunological system of the body is not as complete as an adult system until 6 years of age [*22*]. As a result, it is possible that optimum cognitive development of the human brain depends on the many hormones and bioactive substances found in human milk.

Finally, what are the explanations for the long-term effect of breastfeeding on

Table 3 Standardized direct, indirect and total effects of breastfeeding on developmental milestones and cognitive tests at different ages by sex

Variable	Females						Males					
	Direct effect		Indirect effect		Total effect		Direct effect		Indirect effect		Total effect	
	r	SE	*r*	SE	*r*	SE	*r*	SE	*r*	SE	*r*	SE
Developmental milestones	-0.12*	0.02	-		-0.12*	0.02	-0.01	0.02	-	-	-0.01	0.02
Cognitive tests between age 8 and 15 years	-	-	0.01*	0.002	0.01*	0.002	0.08*	0.014	0.0005	0.001	0.0805*	0.014
Reading tests at age 26 years	-	-	0.00	0.002	0.00	0.002	-0.01	0.01	0.06*	0.01	0.05*	0.02
Visual and memory tests at age 43 years	0.050*	0.02	0.001	0.00	0.051*	0.02	-	-	0.005	0.005	0.005	0.005

*$P < 0.05$.
r = standardized path coefficient; SE = standard error.

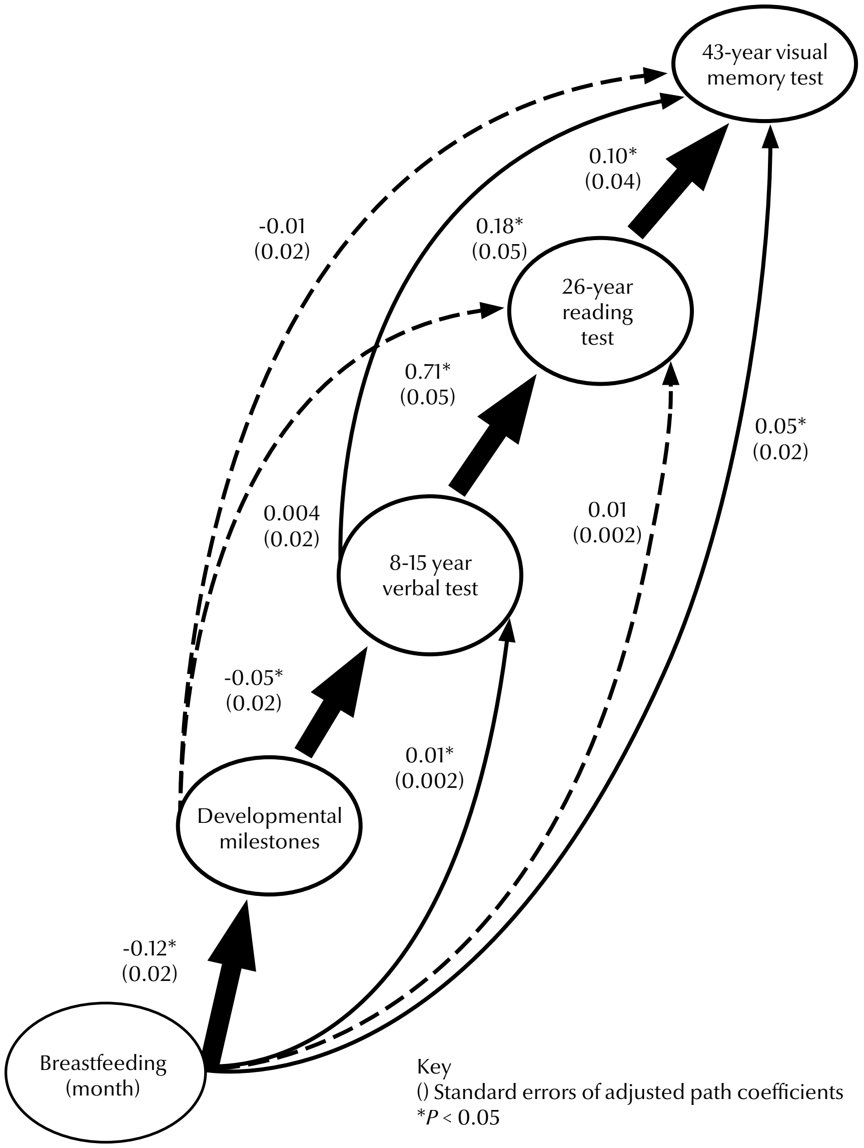

Figure 1 Path diagram model of the influence of breastfeeding on developmental milestones and cognitive performance for the female cohort (unadjusted goodness-of-fit index = 1.00; adjusted goodness-of-fit index = 0.99; *n* = 2548)

cognitive performance at age 26 years and 43 years found in this study cohort? The continuity theory of cognitive performance over time was another hypothesis which was tested in the present study using path analysis. We found an indirect effect of breastfeeding on reading scores at age 26 years for male subjects and a direct effect on visual scores at age 43 years in female subjects. The life-span approach to development emphasizes that developmental change occurs during adulthood as well as during childhood, so that physical and mental status at any age in the life span rests upon the accumulated events and influences earlier in life [20]. To understand the cognitive performance of an individual, one must have knowledge of that person's past life and experiences. Some psychologists and neurologists believe that the relationship between early life and later cognitive function should be studied in a longitudinal study [15]. In the present study a correlation matrix was studied by path analysis to examine the mechanism of the continuity of cognitive ability over the life course.

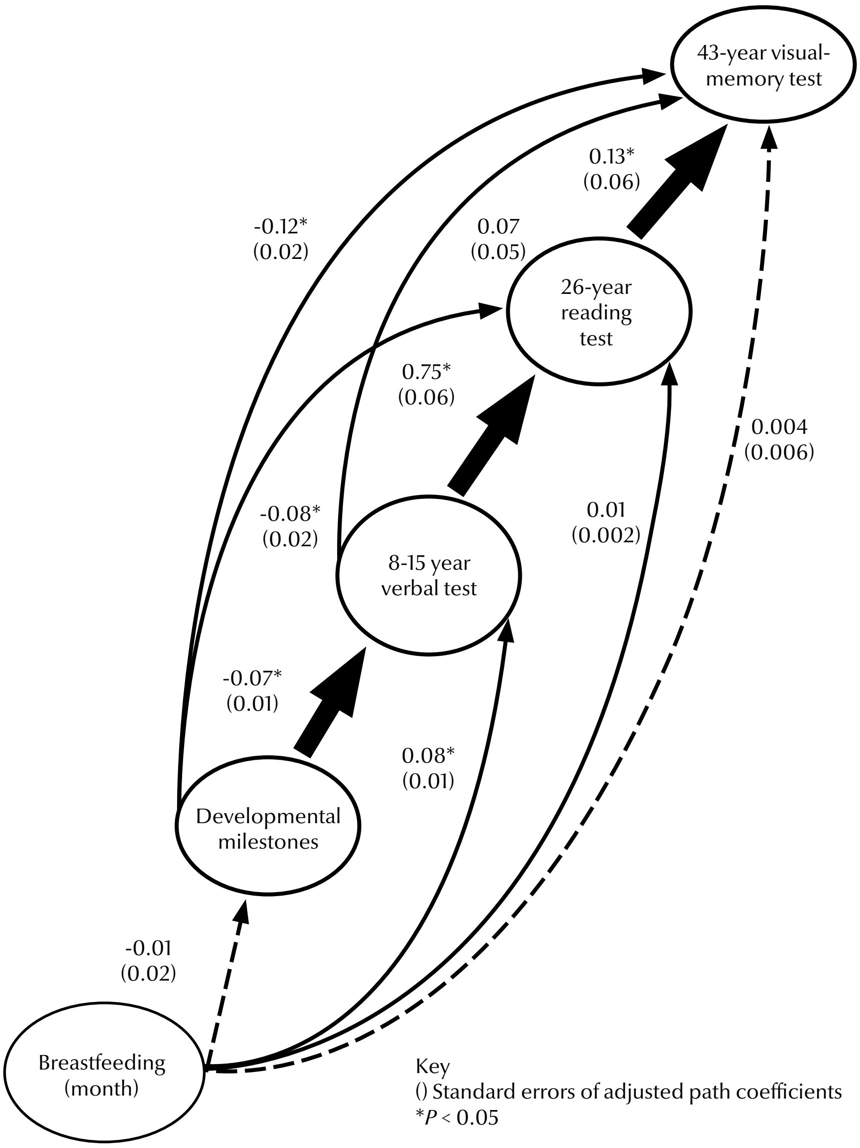

Figure 2 Path diagram model of the influence of breastfeeding on developmental milestones and cognitive performance for the male cohort (unadjusted goodness-of-fit index = 1.00; adjusted goodness-of-fit index = 0.98; *n* = 2814)

One possible reason the relationship between breastfeeding and test scores at age 43 years was significant for females but not for males might be that the attachment between female children and their mothers persists longer than for males [23]. We should note that one of the tests at age 43 years assessed visual performance and, as Bowlby cited from other studies [23], during breastfeeding in the early weeks of life, infants are able to focus clearly only on close subjects such as the mother's face, and that once fixated they tend to track the objects with their eyes and head. Therefore, this early fixation and attachment in girls may explain the significant relation between longer breastfeeding and cognitive performance at age 43 years.

A further explanation is that there may be a different behaviour of the mother towards female and male children; mothers talk more, display more skin-to-skin attachment, and show more "face-to-face" response towards girls than boys [24]. The vulnerable period of the effect of infant nutrition on the development of the brain and on the subsequent improvement in intelligence is another explanation from the literature. Animal and human experimental studies have suggested that the critical period is different in different species so that major developmental events in the brain of humans occurs in the prenatal and postnatal periods up to age 9 months [25,26].

In summary, combination of our findings with others suggests that the significant relationship between breastfeeding and cognitive performance found by other investigators has its origin in the prenatal and postnatal periods.

A limitation in this study was attrition in the cohort sample. Wadsworth et al.'s analysis of the same cohort, however, showed that the sample was still representative when they compared a proportion of the cohort with the general population [16]. We suggest that the data of this cohort should be combined with the data of its offspring cohort to study the effect of early life events on later life cognitive performance. Another point is that several confounding variables were included in the statistical modelling to find the adjusted size effect of breastfeeding. However, this does not limit the generalization of the results because some of the confounders, such as social class, were the same variables which were determined on several occasions and were correlated to each other. In addition, the sample size in each social group was sufficient to make inferences for different subpopulations. Finally, we suggest that the new data which were collected in year 2000, and we did not have access to, can be incorporated into the data analysis to follow the effect of early life breastfeeding on later life cognitive ability more thoroughly.

Conclusion

The main conclusion from the present study is that to trace the correlation between breastfeeding and cognitive abilities in later life, attention should be directed not only to early life but also to prenatal life and maternal diet during pregnancy. Also, the only way to deal with causal lags which are longer than the interval between measurements is to collect more data at different times of the life span to draw an accurate path from the prenatal events into old age.

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