Dietary patterns in infancy and cognitive and neuropsychological function in childhood

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Abstract

Background: Trials in developing countries suggest that improving young children's diet may benefit cognitive development. Whether dietary composition influences young children's cognition in developed countries is unclear. Although many studies have examined the relation between type of milk received in infancy and subsequent cognition, there has been no investigation of the possible effect of variations in the weaning diet.

Methods: We studied 241 children aged 4 years, whose diet had been assessed at age 6 and 12 months. We measured IQ with the Wechsler Pre-School and Primary Scale of Intelligence, visual attention, visuomotor precision, sentence repetition and verbal fluency with the Developmental Neuropsychological Assessment (NEPSY), and visual form-constancy with the Test of Visual Perceptual Skills.

Results: In sex-adjusted analyses, children whose diet in infancy was characterised by high consumption of fruit, vegetables and home-prepared foods ('infant guidelines' dietary pattern) had higher full-scale and verbal IQ and better memory performance at age 4 years. Further adjustment for maternal education, intelligence, social class, quality of the home environment and other potential confounding factors, attenuated these associations but the relations between higher 'infant guidelines' diet score and full-scale and verbal IQ remained significant. For a standard deviation increase in 'infant guidelines' diet score at 6 or 12 months full scale IQ rose by 0.18 (95% CI 0.04 to 0.31) of a standard deviation. For a standard deviation increase in 'infant guidelines' diet score at 6 months verbal IQ rose by 0.14 (0.01 to 0.27) of a standard deviation. There were no associations between dietary patterns in infancy and 4-year performance on the other tests.

Conclusions: These findings suggest that dietary patterns in early life may have some effect on cognitive development. It is also possible that they reflect the influence of unmeasured confounding factors.

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Introduction

There is considerable evidence from observational studies in developing countries linking undernutrition in early life with poorer cognitive and neuropsychological development (Grantham-McGregor & Baker-Henningham, 2005). Interpreting such associations is problematic as undernourished children are more likely to come from disadvantaged backgrounds, to have parents with lower levels of education, a less stimulating home environment and to have been born with a low birthweight. Such factors are likely to confound any link between diet in early life and development. However, data from trials in developing countries suggest that improving children's nutritional status, perhaps particularly in the first two years of life, can benefit cognitive and neuropsychological function, at least in the short-term (Neumann, Murphy, Gewa, Grillenberger, & Bwibo, 2007; Grantham-McGregor & Baker-Henningham, 2005).

In developed countries, research into the relation between diet in early life and cognitive or neuropsychological development has largely concentrated on the potential importance of the type of milk received in infancy (Anderson, Johnstone, & Remley, 1999). Many studies have shown that breastfed children perform better on tests of cognitive function, but there is evidence that this may be largely due to confounding by maternal intelligence (Der, Batty, & Deary, 2006). A recent trial of breastfeeding promotion found evidence that suggests prolonged breastfeeding might improve cognitive development (Kramer et al., 2008), though interpretation of this is complicated by lack of blinding to intervention status among the pediatricians who administered the cognitive tests. Several randomized controlled trials have examined whether prenatal exposure to omega-3 fatty acids via maternal diet influences cognitive outcomes but results have been inconsistent (Eilander, Hundscheid, Osendarp, Transler, & Zock, 2007). Few studies have examined whether the composition of the diet that babies receive once they start the transition to solid foods has any effect on their subsequent cognitive performance, though a recent survey from the UK shows that there are wide variations in how babies are fed (Bolling, Grant, Hamlyn, & Thornton, 2007).

We investigated the relation between dietary patterns in infancy and cognitive and neuropsychological function in four-year-old children, controlling for the influence of maternal intelligence, social class, education, quality of the home environment and other potential confounding factors.

Methods

The Southampton Women's Survey

The Southampton Women's Survey (SWS) is a study of a population sample of non-pregnant women aged 20 to 34 years, resident in the city of Southampton, UK. The SWS was started in 1998 (Inskip et al., 2006). Its aim is to identify the maternal influences acting before and during pregnancy that determine fetal growth and development, and to characterise how maternal and intrauterine influences interact with the child's genes and postnatal environment to determine subsequent growth, development and health. The initial study and subsequent follow-ups of the women and their children were approved by Southampton and South West Hampshire Local Research Ethics Committee.

Dietary assessment

Infant diet was assessed at age 6 and 12 months using food frequency questionnaires (FFQ) administered by trained research nurses at a home visit (Robinson et al., 2007). At 6 months of age, for 34 food items the frequency of consumption and amounts consumed over the 7-days preceding the visit were recorded. At 12 months, for 78 food items the frequency of consumption and amounts consumed over the 28-days preceding the visit were recorded. At

both interviews, prompt cards were used to show the foods included in each food group to ensure standardised responses to the FFQ. Portion size was described using household measures, and with the aid of food models. An open section in the same format was included at the end of each FFQ to record frequencies of consumption and amounts of any foods that were not listed on the FFQ, provided they were consumed once per week or more. Validation studies within SWS have indicated that the questionnaires are useful tools for assessing the food intakes of healthy infants (Marriott et al., 2007).

Dietary patterns analysis

Dietary patterns were defined using principal components analysis (PCA) (Joliffe & Morgan, 1992). This is a multivariate statistical technique that produces new variables that are uncorrelated linear combinations of the dietary variables that maximise the explained variance. Full details of this analysis have been described previously (Robinson et al., 2007).

In brief, the foods listed in the food frequency questionnaires were grouped on the basis of similarity into food groups which were then entered into a PCA (Robinson et al., 2007). The first component defined by the PCA of the FFQ data at 6 months was characterised by a high frequency of consumption of vegetables, fruit, meat and fish, other home-prepared foods and breast milk, and a low frequency of consumption of commercial baby foods in jars and lower consumption of formula milk. As this component describes a pattern of foods that conforms to the feeding guidelines as recommended in infant feeding manuals (Department of Health, 2006), we called it the 'infant guidelines' pattern. The second component at 6 months was characterised by a high frequency of consumption of bread, savoury snacks, biscuits, squash, breakfast cereals and chips, but by low consumption of breast milk and baby rice. Since this component was noteworthy for frequent consumption of foods found in the adult diet and low consumption of weaning foods, we called it the 'adult foods' pattern. The PCA of the FFQ data at 12 months produced two components. The first was very similar to the 'infant guidelines' pattern at 6 months, and was characterised by high frequency of consumption of fruit, vegetables and home-prepared foods. The second component was similar to the 'adult foods' pattern at six months, and was characterised by high frequency of consumption of crisps and savoury snacks, processed meat, squash and chips. For each component, individual infants were allocated a score that was derived from the component's coefficients for the food groups and the reported frequencies of consumption. The distributions of these scores were standardised to have zero mean and unit variance (Robinson et al., 2007).

Cognitive and neuropsychological assessment

At the age of 4 years, children's full-scale, verbal and performance intelligence was assessed at home by psychologists using the Wechsler Pre-School and Primary Scale of Intelligence (3rd edition; WPPSI-III UK) (Wechsler, 2004). Attention, sensorimotor ability, memory and language were assessed by means of four subtests from the Developmental Neuropsychological Assessment (NEPSY): these subtests were visual attention, visuomotor precision, sentence repetition and verbal fluency (Korkman, Kirk, & Kemp, 1997). We assessed visual perception abilities separate from motor skills using the visual form-constancy subtest of the Test of Visual-Perceptual Skills (Non-Motor) (Gardner, 1996).

Maternal and child characteristics

Details of mother's date of birth, number of previous births, educational attainment, and her and her partner's current occupation were obtained at interview prior to the index pregnancy. Educational attainment was defined in 6 groups according to the mother's highest academic qualification. Data on current occupation was used to define social class in 6 groups according to the highest social class of either the mother or her partner (Office of Population

Censuses and Surveys, 1990). At birth, the child was weighed using digital scales. During the 4-year home visit, maternal intelligence was assessed with the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). The quality of the child's home environment was assessed using the short form of the Home Observation for Measurement of the Environment scale (HOME-SF) (Caldwell & Bradley, 1984). Scores on this scale predict cognitive and social development in young children (Bradley et al., 1989).

Participants

There were 1981 singleton live births to women in the SWS up to the end of 2003. After exclusion of infants with major congenital abnormalities (2), and neonatal deaths (6), there were 1973 SWS infants for postnatal follow-up. Of these infants, 1644 (83%) were visited within 2 weeks of their 6-month birthday and 1618 (82%) were visited within a period 2 weeks before and 3 weeks after their 12-month birthday. During these visits, research nurses administered questionnaires to mothers to assess her child's diet. In total, 1434 (73%) infants had their diet assessed at both 6 and 12 months of age. A sub-set of children with dietary data in infancy were invited to take part in follow-up at age 4 years to assess bone mass, body composition and cognitive function. For the cognitive function follow-up study, we aimed to recruit around 400 children as power calculations suggested that a sample size of this magnitude would give us 90% power to detect a 5-point difference in IQ between milk feeding groups in infancy. When mothers brought their children for a DXA scan at the Southampton Osteoporosis Centre, they were given an information sheet about the cognitive function study. Psychologists from the research team subsequently contacted the mothers by phone and invited them to take part in the study. During the three years of the study, 396 mothers were contacted. Of these, 268 (68%) agreed to take part and were visited at home by the psychologists. Written informed consent was obtained from the mothers at the start of the visit. The analyses in this report are based on 241 children who took tests of cognitive and neuropsychological function at age 4 years and had complete data on covariates.

Statistical analysis

All continuous variables were checked for normality and transformed where necessary using logarithms. We used t-tests and the Mann-Whitney test to examine characteristics of the participants compared to non-participants and cognitive and neuropsychological test scores in relation to sex. Multiple linear regression was used to examine the relation between test scores, expressed as standard deviation scores, and dietary patterns in infancy. We used Pearson and Spearman correlation coefficients to examine the relation between dietary patterns and maternal characteristics.

Results

Characteristics of the 241 mothers and children who took part in the present study are shown in Table 1. Compared to the rest of the SWS cohort with children born in 1999-2003 who were not invited to take part in this study or declined to do so, the mothers who participated tended to have a higher level of educational attainment (p=0.049), higher social class (p=0.002) and had breastfed for longer (p<0.001). 12% of mothers who participated were from manual social classes compared with 20% of those who did not take part. 53% of mothers who participated had breastfed for 4 or more months compared with 39% of mothers who did not take part.

There was wide variation in dietary pattern scores in infancy among the children who took part in the present study. Standardized scores for the 'infant guidelines' pattern at 6 or 12 months ranged from −3.03 to 2.68, with higher scores indicating more frequent consumption of fruit, vegetables, home-prepared foods and lower consumption of commercial baby food

in jars. Standardized scores for the 'adult foods' pattern ranged from −3.23 to 3.03, with higher scores indicating more frequent consumption of crisps and savoury snacks, processed meat, biscuits, squash and chips and lower consumption of baby rice. There were no significant differences between the participants and the non-participants in standardized 'adult foods' score at 6 or 12 months of age, or 'infant guidelines' score at 6 months, but children who participated in this study had higher mean 'infant guidelines' scores at 12 months compared with those who did not take part (mean (SD) 0.170 (0.93) *vs* −0.028 (1.00) p=0.01).

Table 2 shows 'infant guidelines' and 'adult foods' diet scores in infancy and cognitive and neuropsychological test scores at age 4 years according to sex. There were no differences between boys and girls in dietary pattern scores at either 6 or 12 months of age. Girls gained significantly higher scores than boys on full-scale and verbal IQ, visual attention, visuomotor precision and sentence repetition, but there were no differences between the sexes in performance IQ, visual form constancy or verbal fluency.

There were significant positive associations between 'infant guidelines' diet scores at 6 and 12 months and cognitive function at age 4 years in linear regression analyses adjusting for sex alone (Table 3). For a standard deviation increase in 'infant guidelines' diet score at 6 months, full-scale IQ rose by 0.23 (95% CI 0.11 to 0.36), verbal IQ by 0.23 (0.10 to 0.35) and sentence repetition score by 0.22 (0.09 to 0.36) of a standard deviation. Similar associations were found between 'infant guidelines' diet score at 12 months and these measures of cognitive function. The effect on full-scale and verbal intelligence at age 4 years of these dietary pattern scores in infancy was similar in magnitude to the effect of maternal intelligence on that of her child: for a standard deviation increase in maternal IQ, full-scale IQ rose by 0.22 (0.11 to 0.34) of a standard deviation and verbal IQ by 0.25 (0.13 to 0.36) of a standard deviation. Higher 'infant guidelines' diet scores at 12 months were also associated with higher performance IQ and with greater verbal fluency at age 4 years. There were no associations between 'infant guidelines' diet score at 6 or 12 months and visual attention, visuomotor precision or visual form constancy. Children who had a higher 'adult foods' diet score at 12 months of age had a lower verbal IQ and a poorer performance on the test of visual form constancy, but apart from this, there were no associations between this pattern of diet in infancy and cognitive or neuropsychological test scores at 4 years (Table 3).

A previous study of this cohort showed that mothers whose children had a high 'infant guidelines' diet score either at 6 or at 12 months tended to be older and better educated, and their children were more likely to be of lower birth order (Robinson et al., 2007). By contrast, mothers whose children had a high 'adult foods' diet score in infancy tended to be younger and less educated, and their children were more likely to be of higher birth order (Robinson et al., 2007). In the present study, a higher 'infant guidelines' diet score at 12 months was strongly associated with higher maternal intelligence (r=0.24, p<0.0001) and a higher quality home environment, as measured by HOME score (r=0.30, p<0.0001), and weakly associated with more advantaged social class (r_s=−0.12, p=0.063). Mothers whose children had a higher 'adult foods' diet score at 12 months tended to have a lower IQ (r= −0.17, p=0.007) and to come from a more disadvantaged social class (r_s=0.28, p<0.0001), though quality of the home environment was not associated with this pattern of diet (r= −0.09, p=0.16).

In multivariate analyses, adjusting for the potential confounding effects of birth order, birthweight, gestational age, maternal age, education, intelligence, social class and HOME score, a higher 'infant guidelines' diet score at 6 and 12 months remained associated with a slightly higher full-scale IQ at the age of 4 years: for a standard deviation increase in 'infant

guidelines' diet score at either 6 or 12 months, full scale IQ rose by 0.18 (95% CI 0.04 to 0.31) of a standard deviation (Table 4). Higher 'infant guidelines' diet score at 6 months, though not at 12 months, remained associated with a higher verbal IQ at 4 years: for a standard deviation increase in 'infant guidelines' diet score at 6 months, verbal IQ rose by 0.14 (95% CI 0.01 to 0.27) of a standard deviation. Adjustment for potential confounding factors attenuated the associations between 'infant guidelines' diet score at 6 and 12 months and sentence repetition scores at age 4, though the relation with diet score at 6 months remained of borderline statistical significance. After multivariate adjustment there were no associations between 'adult foods' diet scores in infancy and verbal IQ or visual form constancy scores at age 4.

In addition to eating more fruit, vegetables and home-prepared foods, children who had higher 'infant guidelines' diet scores at age 6 months tended to be breastfed for longer. The additional inclusion of duration of breastfeeding in the multivariate-adjusted linear regression models had no effect on the associations described above between 'infant guidelines' diet scores at 6 and 12 months and intelligence at age 4 years.

Discussion

In this follow-up study, we found that children who had a pattern of diet in infancy characterised by higher intakes of fruit, vegetables and home-prepared foods (described here as the 'infant guidelines' pattern) gained slightly higher scores on tests of full-scale and verbal intelligence at age 4 years. These associations persisted after adjustment for potential confounding factors, including maternal intelligence, social class, education, age, HOME scores and birth order. We found no relation between dietary patterns in infancy and performance on other tests of cognitive or neuropsychological function at age 4 after multivariate adjustment.

Comparison with other studies

No previous studies have examined the relation between dietary patterns in infancy and subsequent cognitive or neuropsychological function. In the UK, government guidelines advise parents to provide their child with a varied diet from 6 months of age, including fruit and vegetables, starchy foods and meat and fish, and encourage them to use home-prepared foods rather than commercial baby foods (Department of Health, 2006). Our results suggest that babies who are given a pattern of diet very similar to these guidelines in infancy tend to be slightly more intelligent at the age of 4 years, at least as regards full-scale and verbal IQ. We found no associations between this pattern of diet and performance IQ after adjustment for potential confounders.

Studies in this cohort (Robinson et al., 2007) and in the Avon Longitudinal Study of Parents and Children (North & Emmett, 2000; Northstone & Emmett, 2005) have shown that many of the maternal characteristics known to be associated with cognitive development in the child - such as educational attainment, age, number of previous births - are strong determinants of the pattern of diet mothers feed their children. In the present study, maternal IQ, social class and quality of the home environment, as measured by HOME score, were associated both with dietary pattern in infancy and cognitive performance at age 4. Adjustment for all these factors, together with birthweight, gestational age and sex, attenuated the associations we found between 'infant guidelines' diet scores in infancy and IQ at age 4 but the relations with full-scale and verbal IQ remained significant.

While these findings suggest that babies who receive a diet in infancy that accords more closely with recommendations might have better cognitive outcomes, there are other possible explanations for our results. A link between 'infant guidelines' diet score and later

IQ could have arisen due to reverse causation if poorer neurodevelopment resulted in a reluctance on the part of the baby to eat vegetables, fruit, meat and fish and other home prepared foods. It has been suggested that poorer neurodevelopment might underlie the associations shown in some studies between failure to thrive in infancy and slightly impaired cognitive function in childhood (Corbett & Drewett, 2004; Emond, Blair, Emmett, & Drewett, 2007). Lower 'infant guidelines' scores in infancy were associated with greater frequency of consumption of commercial baby foods which might be preferred by developmentally slower babies if, for instance, they find the transition to solids difficult. We had no measures of neurodevelopment in infancy so were unable to examine this. However, we think reverse causation is unlikely to account for our results. Previous analyses in this cohort have shown that a major determinant of the qualitative differences in the infant diet is the quality of the mother's diet (Robinson et al., 2007). Babies with lower 'infant guidelines' diet scores tend to be those whose mothers had less 'healthy' dietary patterns, characterised by lower intakes of fruit, vegetables, rice, pasta and wholemeal bread and higher intakes of sugar and white bread (Robinson et al., 2007). What babies eat when they begin the transition to solid food is strongly linked to the food on offer in their family. Another explanation might be that our findings arose by chance, though our study of 241 children had over 90% power to detect differences in full-scale and verbal IQ of the size found here. It is also possible that these findings reflect the influence of unmeasured aspects of the child's environment, such as father's intelligence, or of unmeasurable potential confounders, such as devoted parenting, though it is worth noting that multivariate adjustment for quality of the home environment and other factors had only a small attenuating effect on the relations between 'infant guidelines' diet score and full-scale IQ.

If the association between 'infant guidelines' diet scores in infancy and later IQ is not the result of confounding or reverse causation, what might account for it? One possibility is that children who had high scores for this particular pattern of infant diet, characterised by high consumption of fruit and vegetables, and home-prepared foods, including fish and meat, received an optimal supply of micronutrients that are important for cognitive development (Bryan et al., 2004). A recent study of 6-year-olds suggests that even in well-nourished populations, children with higher intakes of folate and iron tend to have a higher IQ (Arija et al., 2006). Further analyses of the relations between dietary patterns and micronutrient intakes in this cohort will be needed to explore this issue. Another possibility might be that the dietary pattern of babies with high 'infant guidelines' scores in infancy has a positive effect on brain development during a time when brain growth velocity is high. Recent evidence in children born preterm found that a protein- and micronutrient-enriched formula in early infancy was associated with a larger caudate volume and a higher verbal IQ in adolescence, though this relation was only present in boys (Isaacs et al., 2008).

We found little indication that eating a diet characterised by a high frequency of consumption of bread, savoury snacks, biscuits, squash, breakfast cereals and chips in infancy might have detrimental effects on cognitive or neuropsychological development. Although a higher 'adult foods' score at 12 months of age was associated with lower verbal IQ at age 4 years in sex-adjusted analyses, this association was severely attenuated after further adjustment for maternal intelligence, social class and other potential confounding factors. It is possible that we might have found a more robust association between this pattern of diet and later cognition if our sample had included more mothers from lower socioeconomic groups, but there was no indication that 'adult foods' scores differed between those children who did or did not participate in this follow-up study.

The use of principal components analysis to identify major patterns of dietary behaviour based on food frequency questionnaire data is becoming increasingly common. The reproducibility and validity of the major dietary patterns thus identified have been shown to

be reasonable (Hu et al., 1999). To our knowledge, no previous study has carried out a principal components analysis of infant dietary data, but the variations in the 'infant guidelines' pattern and in consumption of the foods that characterise this pattern (such as fruit, vegetables and home-prepared foods) are very comparable to those observed in the UK Department of Health's national survey of infant feeding (Bolling, Grant, Hamlyn, & Thornton, 2007).

Strengths and weaknesses

The children we studied were born to a general population sample of women living in Southampton (Inskip et al., 2006). Detailed dietary assessments were made twice during the first year of life. Child psychologists, who had not seen the infant dietary data, carried out a comprehensive cognitive and neuropsychological assessment of the children at the age of four years. The psychologists also measured the mother's intelligence and assessed the quality of the home environment using the HOME-SF (Caldwell & Bradley, 1984), thus allowing us to control for these important potential confounders in our analyses. The study also has some limitations. Compared to women who did not take part, the women who agreed to participate in this follow-up study of cognitive development were of higher social class, slightly better educated and a higher proportion had breastfed their child. We were able to carry out 4-year cognitive and neuropsychological assessments on only a small subset of the children who had their diet assessed in infancy. As all comparisons were made within the study sample it is unlikely that this would have biased our findings unless the relation between dietary patterns and cognitive or neuropsychological function is different in those who did not take part in our study. It is possible, however, that if our sample had been bigger or contained a greater proportion of women with lower educational attainment and from manual social classes, the effect of dietary patterns in infancy on the child's cognitive development might have been larger.

In this follow-up study of 4-year-olds, we found that full-scale and verbal IQ was higher in children whose diet in infancy was characterised by more frequent consumption of fruit, vegetables and home-prepared foods. The associations persisted after adjustment for potential confounding factors, including birth order, gestational age, birthweight, maternal age, IQ, education, social class and HOME score. These findings suggest that even in well-nourished populations, dietary patterns in early life have some effect on cognitive development, though it is also possible that they merely reflect the influence of other confounding factors in the child's environment that we were unable to measure.

Key points

- Trials in developing countries suggest that improving young children's diet may benefit cognitive development. In developed countries, there is wide variation in how young children are fed once they start being weaned, but the relation between dietary patterns in infancy and subsequent cognitive and neuropsychological function is unknown.

- Children who had a pattern of diet in infancy characterised by higher intakes of fruit, vegetables and home-prepared foods gained slightly higher scores on tests of full-scale and verbal intelligence at age 4 years.

- Even in well-nourished populations, dietary patterns in early life may have some effect on cognitive development, though these findings could also be due to unmeasured confounding factors.

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Table 1

Characteristics of the study participants

Characteristic	No (%) or Mean (SD)
Mother	
Educational qualifications, n (%)	
None	3 (1.24)
CSE	28 (9.54)
O levels	66 (27.4)
A levels	74 (30.7)
HND	18 (7.47)
Degree	57 (23.7)
Social class, n (%)	
Professional	24 (9.96)
Management and technical	121 (50.2)
Skilled non-manual	68 (28.2)
Skilled manual	20 (8.30)
Partly skilled	7 (2.90)
Unskilled	1 (0.41)
Duration of breastfeeding	
Never	31 (12.9)
<4 months	83 (34.4)
4 months	127 (52.7)
HOME score	22.0 (2.03)
Age at birth, yrs	30.4 (3.45)
Full-scale IQ	108.3 (11.3)
Child	
Female, n (%)	111 (46.1)
Birth order, n (%)	
1st	121 (50.2)
2nd	88 (36.5)
3rd or higher	32 (13.3)
Birth weight, kg	3.44 (0.53)
Gestational age, wks	39.7 (1.90)
Age, yrs	4.40 (0.16)

Table 2

Dietary patterns scores in infancy and cognitive and neuropsychological test scores at 4 years in boys and girls. Values are means (SD) unless otherwise stated

	Boys (n=130)	Girls (n=111)
Dietary patterns scores in infancy		
'Infant guidelines' at 6 m	0.086 (0.98)	0.118 (0.89)
'Infant guidelines' at 12 m	0.152 (0.93)	0.191 (0.95)
'Adult foods' at 6 m	−0.124 (1.07)	−0.018 (1.00)
'Adult foods' at 12 m	0.014 (1.03)	0.088 (0.88)
Test scores at age 4 yr		
Full-scale IQ	105.4 (12.8)	111.5 (11.1) [***]
Verbal IQ	110.3 (15.1)	115.5 (13.9) [**]
Performance IQ	105.5 (14.5)	106.3 (12.4)
Visual form constancy[§]	8.0 (6-9)	8.0 (6-10)
Visual attention	11.8 (1.20)	12.4 (1.24) [***]
Visuomotor precision	9.62 (3.15)	10.7 (2.64) [**]
Sentence repetition	10.1 (2.59)	10.9 (2.15) [*]
Verbal fluency	10.7 (2.91)	11.3 (2.58)

[§]Median (interquartile range)

[*]
p<0.05

[**]
p<0.01

[***]
p<0.001

Table 3

Sex-adjusted associations between standardized dietary pattern scores at 6 and 12 months of age and standardized cognitive and neuropsychological test scores at 4 years of age

	Regression coefficient (95% confidence interval)							
	Full-scale IQ	Verbal IQ	Performance IQ	Visual form constancy scaled score	Visual attention scaled score	Visuomotor precision scaled score	Sentence repetition scaled score	Verbal fluency scaled score
'Infant guidelines' diet score								
6 months	0.23 (0.11, 0.36) ***	0.23 (0.10,0.35) **	0.11 (−0.02, 0.25)	−0.07 (−0.21, 0.06)	0.02 (−0.11, 0.14)	−0.06 (−0.20, 0.07)	0.22 (0.09, 0.36) **	0.12 (−0.02, 0.25)
12 months	0.24 (0.12, 0.37) ***	0.21 (0.07, 0.34) **	0.13 (0.01, 0.27) *	0.02 (−0.14, 0.17)	−0.02 (−0.15, 0.10)	0.05 (−0.08, 0.19)	0.21 (0.07, 0.34) **	0.14 (0.01, 0.28) *
'Adult foods' diet score								
6 months	−0.09 (−0.21, 0.03)	−0.09 (−0.20, 0.03)	−0.03 (−0.16, 0.09)	−0.14 (−0.27, −0.02) *	−0.04 (−0.16, 0.07)	−0.06 (−0.18, 0.06)	−0.07 (−0.19, 0.05)	−0.05 (−0.17, 0.08)
12 months	−0.07 (−0.19, 0.05)	−0.16 (−0.28, −0.03) *	0.04 (−0.09, 0.16)	−0.10 (−0.23, 0.03)	0.05 (−0.07, 0.16)	0.09 (−0.03, 0.22)	−0.09 (−0.22, 0.04)	−0.08 (−0.21, 0.05)

***
$p < 0.001$

**
$p < 0.01$

*
$p < 0.05$

Table 4

Multivariate-adjusted[§] associations between standardized dietary pattern scores at 6 and 12 months of age and standardized cognitive and neuropsychological test scores at 4 years of age

	Regression coefficient (95% confidence interval)							
	Full-scale IQ	Verbal IQ	Performance IQ	Visual form constancy scaled score	Visual attention scaled score	Visuomotor precision scaled score	Sentence repetition scaled score	Verbal fluency scaled score
'Infant guidelines' diet score								
6 months	0.18 (0.04, 0.31) **	0.14 (0.01, 0.27) *	0.10 (−0.04, 0.24)	−0.14 (−0.29, 0.02)	0.05 (−0.08, 0.19)	−0.07 (−0.21, 0.07)	0.13 (−0.001, 0.27)	0.10 (−0.05, 0.25)
12 months	0.18 (0.04, 0.31) **	0.11 (−0.03, 0.25)	0.12 (−0.02, 0.26)	−0.09 (−0.24, 0.06)	−0.05 (−0.19, 0.08)	0.01 (−0.13, 0.16)	0.10 (−0.05, 0.24)	0.12 (−0.03, 0.28)
'Adult foods' diet score								
6 months	−0.02 (−0.14, 0.11)	−0.01 (−0.13, 0.12)	0.01 (−0.13, 0.13)	−0.11 (−0.25, 0.02)	−0.08 (−0.20, 0.05)	−0.10 (−0.22, 0.03)	0.05 (−0.08, 0.17)	0.01 (−0.13, 0.14)
12 months	0.02 (−0.10, 0.15)	−0.08 (−0.20, 0.05)	0.11 (−0.02, 0.25)	−0.04 (−0.19, 0.10)	−0.01 (−0.12, 0.13)	0.06 (−0.07, 0.19)	0.01 (−0.13, 0.13)	−0.04 (−0.19, 0.10)

[§] adjusted for sex, birth order, gestational age, birthweight, maternal age, IQ, social class, education and HOME score

**
p<0.01

*
p<0.05