

Maternal diet rich in saturated fat during breastfeeding is associated with atopic sensitization of the infant

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Objective: To investigate the impact of maternal diet during breastfeeding on atopic sensitization of infants at risk.

Design: Prospective cohort study.

Setting: Turku University Central Hospital, Finland.

Subjects and methods: Altogether 114 infants with a family history of atopic disease were followed during their first year of life. The mothers completed a 4 day food record during breastfeeding just before the infants were 3 months old. Atopic sensitization of the infants was determined by a positive skin prick test result at 12 months.

Results: Positive skin prick test reactivity to at least one antigen was detected in 27/114 (24%) infants at 12 months. The energy intake of the mothers was low, mean 8.0 MJ/day (95% CI 7.7–8.3), and the proportion of energy derived from fat was high, mean 36.6 E% (95% CI 35.6–37.6). Atopic mothers had a higher intake of total fat and saturated fat and a lower intake of carbohydrate as a percentage of total energy intake than non-atopic mothers; $P=0.017$, $P=0.050$, $P=0.004$ respectively. Maternal intake of saturated fat during breastfeeding was associated with atopic sensitization of the infant, OR = 1.16 (95% CI 1.001–1.36); $P=0.048$ irrespective of the maternal atopic status.

Conclusions: Our results show that an unbalanced maternal diet during breastfeeding may be a risk factor underlying the later development of atopic sensitization of the infant regardless of maternal atopic disease. The observation thus extends findings implying that early nutrition programmes the subsequent health of the child to the risk of developing atopic disease.

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Descriptors: maternal diet; breastfeeding; nutrient intake; saturated fat; atopy

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Introduction

Breast milk provides optimal nutrition and immunological protection for the newborn infant. Exclusive breastfeeding is recommended for 4–6 months of age with continued breastfeeding for 12 months (American Academy of Pediatrics, 1997). A balanced, nutritious maternal diet will ensure both the quality and the quantity of breast milk without depletion of maternal stores. Additional energy needed during breastfeeding is estimated to be about 2.0 MJ (500 kcal)/day (Dewey, 1997). Recommended intakes of some nutrients such as calcium and vitamin D are also raised during breastfeeding (Nordic nutrition recommendations, original report 1996). The mother's diet determines the fatty acid composition (Francois *et al.*, 1998) and the concentration of vitamins in breast milk, while the influence on mineral, trace element and electrolyte concentrations appears relatively limited (Lönnerdal, 1986; Emmett & Rogers, 1997).

The question of optimal diet for the lactating mother becomes crucial in atopic families, since breastfeeding is

considered especially beneficial for infants at risk (Saarinen & Kajosaari, 1995). The recent rapid increase in the incidence of atopic diseases in Western industrialized countries has been associated with changing food habits, for example changes in fat consumption (Von Mutius *et al.*, 1998). The dietary approach for mothers of at-risk infants, however, has been centered on elimination diets, the success of which in preventing atopic sensitization remains unresolved (Hide *et al.*, 1994; Zeiger & Heller, 1995). The influence of maternal elimination diets on maternal nutrient intake and thereby on the nutrient composition of breast milk is likewise not known.

The objective of this study was to investigate the impact, if any, of the maternal diet during breastfeeding on atopic sensitization of the infant. To address this issue, qualitative and quantitative food and nutrient intake data on mothers were recorded during breastfeeding of high-risk infants developing or not developing atopic sensitization at 12 months of age. Dietary intakes of atopic and non-atopic mothers were also compared because atopic mothers may often eliminate certain foods from their diet.

Methods

Subjects and study design

A birth cohort of 142 infants were followed up. They fulfilled the primary criterion of the study: a positive family history of atopic disease, ie the mother, the father

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and/or siblings in the family had atopic dermatitis, allergic rhinitis and/or asthma. The next inclusion criterion was breastfeeding for at least 3 months and a completed food record during this period. On this basis 24 infants were excluded. Additionally, the parents of four infants withdrew their participation before the 12 months' clinical examination. Thus the study population comprised 114 mother–infant pairs. Infants were examined at 3, 6 and 12 months of age. Exclusive breastfeeding for 4–6 months was promoted and abstinence from smoking was encouraged.

The outcome variable was atopy of the infant at the age of 12 months, as determined by a positive skin prick test result. Infants were defined as atopics if they yielded a positive skin prick test result, while those with negative results were defined as non-atopic controls.

The study protocol was approved by the Committee on Ethical Practice of Turku University Central Hospital. Written informed consent was obtained from the mothers.

Evaluation of maternal food and nutrient intake

Food intake of the mothers during breastfeeding was evaluated on the basis of a four-consecutive-day food record with household measures. Mothers were asked to complete the records 1–2 weeks before the infants' 3 months examination. Nutrient intakes were calculated with Micro-Nutrica software (version 2.0, Research Centre of the Social Insurance Institution, Turku, Finland), which uses the Food and Nutrient Data Base of the Social Insurance Institution and is constantly updated with manufacturers' data.

Evaluation of atopic sensitization

Skin prick tests were carried out on the volar side of the forearm with a 1 mm, one-peak lancet (Allergologisk Laboratorium A/S, Horsholm, Denmark, ALK). Histamine dihydrochloride (ALK 10 mg/ml) was used as a positive control. Reactions were read at 15 min and half of the histamine reaction size (2+) or more was recorded as positive on the condition that the mean diameter of the wheel was at least 3 mm while the negative control (ALK) at the same time was 0 mm. Antigens tested included milk, containing 1.5% fat (Valio Ltd, Turku, Finland), wheat flour diluted 1:10 (w/v) with 0.9% (w/v) sodium chloride, gliadin diluted 1:1000 (w/v) with 0.9% (w/v) sodium chloride, egg white (ALK), cod (ALK), soybean (ALK), latex (Stallergens, France), birch (ALK), six local grasses (all from ALK), cat (ALK), dog (ALK) and *Dermatophagoides pteronyssimus* allergen Der p1 (ALK). In addition, banana, potato and carrot were tested by prick–prick technique.

Statistics

Results are given as means with 95% confidence interval (CI) in parentheses. The *t*-test for independent samples was used for comparisons between atopic and non-atopic groups. Stepwise logistic regression analysis was used to establish which of the maternal nutrient variables best indicated atopy in the infant.

Results

Atopic sensitization

Positive skin prick test reactivity to at least one antigen was detected in 27 of the 114 infants (23.7%). Of these, six

infants were polysensitized. The most common positive test reactions were for egg (24 cases), milk (7), wheat (2) and cat (2). As shown in Table 1, the duration of breastfeeding, exclusively and overall, was comparable in atopic and control infants, as was their size at birth.

Nutrient intakes of breastfeeding mothers

The mean energy intake of the mothers was 8.0 MJ/day (95% CI 7.7–8.3). The proportion of energy derived from fat was generally high, mean 36.6 E% (95% CI 35.6–37.6), and individual variations in fat intake were large, ranging from 24.7 to 50.7 E%. Fat intake was negatively correlated with vitamin C intake, Pearson $r = -0.25$; $P = 0.007$. As shown in Table 2, the mean intakes of carbohydrates and fibre were lower than recommended. Alcohol intake was very low, mean 0.5 E% (95% CI 0.3–0.7).

When energy nutrient intakes were compared between atopic and non-atopic mothers (Table 2), atopic mothers were shown to have a higher intake of fat ($P = 0.017$), especially of saturated fat ($P = 0.050$) and a lower intake of carbohydrate ($P = 0.004$) than non-atopic mothers.

Assessment of dietary vitamin and mineral intakes of mothers in terms of the Nordic nutrition recommendations (1996) for breastfeeding women (Table 3) showed the mean intakes of vitamins A, E, D, folate, calcium and iron to fall short. Altogether 50/114 mothers (43.9%) consumed multivitamin supplements, 27/114 (23.7%) iron and 21/114 (18.4%) calcium supplements. There were no significant differences in the intake of vitamins and minerals in diet or as supplements between atopic and non-atopic mothers.

Altogether 31/89 (34.8%) of the atopic mothers had eliminated certain foods, for example eggs, fish, nuts, citrus fruits, strawberries or peas, from their diets because they had themselves experienced adverse reactions to these foods. These mothers had a significantly lower intake of vitamin C, mean 84.1 mg/day (95% CI 67.9–101.3), compared to atopic mothers who did not follow elimination diets, 116.9 mg/day (95% CI 100.4–133.4); $P = 0.013$. Atopic mothers observing elimination diets also had a lower intake of carbohydrate, 44.5 E% (95% CI 42.8–46.3) and a higher intake of fat, 38.8 E% (95% CI 36.8–40.7) than atopic mothers who had no dietary regimen, 47.0 E% (95% CI 45.6–48.5) and 36.5 E% (35.0–37.9) respectively; $P = 0.036$ and $P = 0.067$.

Table 1 Clinical characteristics of atopic and control infants

	Atopic infants (<i>n</i> = 27)	Control infants (<i>n</i> = 87)
Birth weight (kg)	3.5 (3.3–3.7)	3.6 (3.5–3.7)
Birth length (cm)	51.0 (50.1–51.9)	50.8 (50.4–51.2)
Head circumference at birth (cm)	35.0 (34.5–35.6)	35.1 (34.8–35.4)
Total IgE (kU/l)	16.8 (8.3–72.4)	6.6 (3.8–17.8)*
Duration of breastfeeding		
exclusively (months)	3.2 (2.6–3.8)	3.3 (3.0–3.7)
total (months)	8.1 (6.4–9.8)	7.5 (6.9–8.2)
Age of the mother (y)	30.3 (28.4–32.3)	29.8 (28.9–30.7)
Mother atopic (%)	23 (85%)	66 (76%)

Data presented as mean (95% CI), except total IgE as median (interquartile range).

*Statistically significant difference, Mann–Whitney *U*-test, $P = 0.002$.

Table 2 Daily intakes of energy, energy nutrients and fibre of breastfeeding atopic and non-atopic mothers

	Atopic mothers (n = 89)	Non-atopic mothers (n = 25)	NNR 1996
Energy (MJ)	8.1 (7.7–8.4)	7.7 (7.0–8.3)	
Protein (g)	76.3 (72.4–80.3)	69.5 (63.8–75.2)	
Protein (E%)	16.1 (15.5–16.6)	15.6 (14.6–16.5)	10–15 E%
Fat (g)	79.3 (74.9–83.6)	70.4 (62.2–78.5)	
Fat (E%)	37.2 (36.0–38.5)	34.4 (32.7–36.0)*	≤ 30 E%
SAFA (E%)	16.1 (15.4–16.7)	14.8 (13.8–15.7)†	≤ 10 E%
MUFA (E%)	12.7 (12.1–13.3)	11.9 (11.2–12.5)	10–15 E%
PUFA (E%)	5.6 (5.3–5.9)	5.2 (4.7–5.6)	5–10 E%
Carbohydrate (g)	220 (209–232)	224 (205–243)	
Carbohydrate (E%)	46.2 (45.0–47.3)	49.6 (47.9–54.1)‡	55–60 E%
Sucrose (E%)	8.5 (8.0–9.1)	9.7 (8.2–11.3)	≤ 10 E%
Fibre (g)	18.0 (16.6–19.4)	16.4 (14.5–18.3)	25–35 g

Mean, 95% CI. NNR, Nordic Nutrition Recommendations, original report (1996).

Statistically significant difference between atopic and non-atopic mothers, * $P=0.017$, † $P=0.050$, ‡ $P=0.004$.

Table 3 Daily dietary intakes of selected vitamins and minerals of breastfeeding mothers

	Daily intake	NNR 1996
Vitamin A (µg RE)	943 (831–1055)	1200
Vitamin E (mg)	9.2 (8.7–9.7)	11
Vitamin D (µg)	3.3 (3.0–3.7)	10
Vitamin C (mg)	111 (97–124)	90
Folate (µg)	257 (243–270)	400
Calcium (mg)	1149 (1069–1229)	1200
Magnesium (mg)	291 (277–304)	280
Iron (mg)	10.3 (9.7–10.9)	12–18
Zinc (mg)	11.2 (10.7–11.7)	11

Mean, 95% CI. NNR, Nordic Nutrition Recommendations, original report (1996).

The association between maternal nutrient intake and infant's atopic sensitization

To consider separately the impact of the mother's atopic status and diet on infant sensitization, and further, to determine the single most important factor in the maternal diet associated with the development of atopy in the infant, a stepwise logistic regression analysis was performed. The intake of saturated fat (E%) was identified as such a factor, OR = 1.16 (95% CI 1.001–1.36); $P=0.048$. When the maternal atopic status was also included in the model, the corresponding results for saturated fat were: OR = 1.15 (95% CI 0.99–1.35; $P=0.070$), while maternal atopy did not significantly increase the risk of atopy in the infant (OR = 1.50, 95% CI 0.45–5.00; $P=0.51$). High intake of saturated fat (>16 E%) together with low vitamin C (<90 mg) intake also tended to increase the risk of atopy (OR = 1.7, 95% CI 0.7–4.5; $P=0.25$), albeit not statistically significantly.

Discussion

There is a strong hereditary element in atopic diseases. Our results show that dietary factors may also have a remarkable impact on atopic sensitization. A maternal diet rich in saturated fat during breastfeeding was seen to be associated with atopic sensitization of the infant regardless of maternal atopic disease. High fat consumption is characteristic of the Western diet; consequently our data support those of previous studies linking the recent rapid increase in atopic disease to food habits in the West (Black & Sharpe, 1997). Our observation is also in concordance with reports indicating that early nutrition exerts a strong impact

on the later health of the child (Lucas, 1998) and extends this notion to include likelihood of developing atopic disease.

The mean energy intake of the mothers here, 8.0 MJ/day was below the recommendations. The reference value for energy intake for 19–30 y old females with low physical activity is 9.2 MJ/day with an average increase during the last trimesters of pregnancy and lactation of 1.1 and 2.0 MJ/day, respectively (Nordic nutrition recommendation, original report, 1996). Together with previous reports (Van Raaij *et al*, 1991; Sadurskis *et al*, 1988; Todd & Parnell, 1994), the present result indicates that breastfeeding can be maintained at lower than recommended energy levels. However, the finding here that a high proportion of energy was derived from fat points to the conclusion that an unbalanced energy nutrient intake may constitute a risk factor associated with the development of atopic disease.

Studies linking dietary fat to allergy have been centered on the effects of individual fatty acids; compiling conclusive evidence in relation to total dietary fat intake is thus difficult. Based on epidemiological studies, it has been suggested that increased consumption of n-6 polyunsaturated fatty acids, especially of linoleic acid, may underlie a heightened risk of atopy. Experimental studies support such a concept in demonstrating that linoleic acid-derived arachidonic acid can be converted to prostaglandin E₂, thus favouring the production of immunoglobulin (Ig)E (Black and Sharpe, 1997). On the other hand, certain individual polyunsaturated fatty acids, eg γ -linolenic acid (18:3 n-6), eicosapentaenoic (20:5 n-3) and docosahexaenoic acid (22:6 n-3), have been associated with anti-inflammatory properties (Kankaanpää *et al*, 1999), a concept again supported by the clinical demonstration that dietary supplementation of γ -linolenic acid reduces the severity of atopic eczema (Biagi *et al*, 1994). It has also been demonstrated that there are differences in fatty acid composition of breast milk associated with atopic disease, possibly indicating disturbed long chain polyunsaturated fatty acid metabolism in atopic subjects (Businco *et al*, 1993; Yu *et al*, 1998). We found differences in total fat and saturated fat intakes between atopic and non-atopic mothers, suggesting that the previous findings could be partly explained by different dietary intake. Moreover, the fatty acid content of breast milk is not directly related to maternal diet during breastfeeding but is also dependent on adipose stores and endogenous fatty acid synthesis (Martin *et al*, 1993). We conclude that the effect of fatty acid intake on atopic disease, both short and long term, is a complex issue

regulated by many mechanisms. Therefore, we suggest that the total fatty acid and other nutrient composition of the diet warrant serious consideration, since with increased intake of some nutrients that of others may decrease and such interactions between nutrients are complex.

In addition to fatty acids, vitamins and minerals also have immunomodulatory effects (Semba, 1998). The importance of the total composition of the diet is emphasized by our finding of an inverse association between intakes of fat and vitamin C. It has been hypothesized that low antioxidant intake may increase liability to develop atopic disease (Seaton *et al.*, 1994). For example, a low dietary intake of vitamin C has been associated with increased bronchial reactivity and the risk of asthma (Soutar *et al.*, 1997). Intakes of vitamins A, E, D, folate, calcium and iron were below the recommendations in our study, as in some previous studies involving breastfeeding women (Todd & Parnell, 1994; Borrud *et al.*, 1993; Mackey *et al.*, 1998). Their low intake may entail a nutritional risk to the mothers and thereby also indirectly to the growth and nutrition of their infants (Isolauri *et al.*, 1999).

The high intake of saturated fat among breastfeeding mothers is an indication of a generally unbalanced diet. The effect of such a diet culminates in infants whose sole source of energy and nutrients is breast milk during the period of rapid growth and development, when the immune response phenotype is also consolidated. Although the precise mechanisms linking maternal diet to atopic sensitization of the infant remain unresolved, the results of the present study call for intensified dietetic counselling to mothers in atopic families during breastfeeding and preferably already during pregnancy. They may also help to identify the high-risk group of mothers and the nutrients whose supplementation might be beneficial. The importance of a balanced and varied maternal diet for the subsequent health and nutritional status of both mother and child should be emphasized in nutritional counselling.

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