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Food and fatty acid intake and atopic disease in adults

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Food and fatty acid intake and atopic disease in adults. M.A. Trak-Fellermeier, S. Brasche, G. Winkler, B. Koletzko, J. Heinrich. ©ERS Journals Ltd 2004.

ABSTRACT: The aim of the study was to assess the relationship between dietary intake of selected foods and fatty acids with atopic disease prevalence in adults.

Data from the European Community Respiratory Health Survey in Erfurt, combined with a 3-day weighed records dietary survey, was used. Complete data was available from 469 males and 333 females aged 20–64 yrs. Multiple logistic regression was applied comparing the highest with the lowest quartile of dietary exposures and linear trends were tested stratified by sex.

In males, margarine intake and a high ratio of omega-6 to omega-3 fatty acids were positively associated with hay fever. In females, a high intake of total fat, palmitoleic and oleic acids were positively associated with sensitisation. A high total fat, high monounsaturated fatty acid and high oleic acid consumption were positively associated with hay fever.

Whilst an excessive intake of fat or imbalance in fat intake, particular of monounsaturated fatty acids, increased the risk for hay fever and allergic sensitisation in females, mostly no significant associations were found for males. Dietary factors were mostly not related with prevalence rates of bronchial hyperresponsiveness and atopic eczema either in males or in females.

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The prevalence of atopic disease continues to rise in industrialised countries. In the search for possible causes, attention has been focused on factors related to Western lifestyle, including dietary habits [1, 2].

It was suggested that the observed increase in the consumption of polyunsaturated fatty acids (PUFA) during the 20th century, due to the wider use of fat from vegetable origin, might have contributed to the observed increase in allergy prevalence [2, 3]. The supply of omega-6 fatty acids, such as linoleic acid, may increase arachidonic acid, which enhances the formation of pro-inflammatory cytokines and of immunoglobulin E (IgE) [2, 4–6]. Available epidemiological evidence is often sex specific [7–9]. Whether these sex differences might be related to known sex-specific dietary habits is highly speculative. Margarine may contain several-fold higher amounts of n-6 fatty acids than butter [9]. Thus, in a study conducted in adult females, dietary intake of n-6 fatty acids was positively associated with hay fever [9]. A European ecological study found no associations between PUFA consumption and sensitisation, but supported the hypothesis that a high intake of monounsaturated fatty acids (MUFA) may lead to the development of atopic disease [10]. Epidemiological studies conducted in children revealed an inverse association between high fish consumption, which provides long chain omega-3 fatty acids, and the prevalence of asthma and bronchial hyperresponsiveness, and inferred that a decreased omega-6 to omega-3 ratio attenuates the inflammatory immune reaction [8–11]. Evidence from a recent clinical study in neonates indicates that altered membrane PUFA profiles during gestation may influence immunological function [12].

This data suggests that the amount and type of dietary fat consumed may be related to the prevalence of atopic disease. Therefore, the current study aimed to explore whether consumption of selected foods, total fat, and specific fatty acids are associated with the prevalence of atopic disease in a cross sectional study conducted on German adults.

Materials and methods

Study design

This is a cross sectional study using data from the European Community Respiratory Health Survey (ECRHS) and MONItoring of Trends and Determinants in CArdiovascular Diseases (MONICA) projects. The methods have been described in detail elsewhere and are summarised briefly for

the current study [13–15]. The ECRHS developed a standardised protocol allowing collection of feasible data on the geographical variation of the asthma and atopic disease prevalence and their treatment in a large number of European countries. Within the framework of the MONICA Study, Erfurt data about dietary habits was collected from the study subjects. One of the objectives of this international programme conducted by the World Health Organisation was to assess the extent to which trends in coronary heart disease morbidity and mortality are related to cardiovascular risk factors, such as dietary habits [16].

Study area

The city of Erfurt, in the former German Democratic Republic, with ~210,000 inhabitants, was selected to participate in the ECRHS because this city met one of the established criteria of having a pre-existing administrative boundary with a population of $\geqslant$150,000 [13].

Sources of data

Data was collected between 1991 and 1992 from a cross sectional study that combined the ECRHS and the MONICA Study. Both studies offered high-quality data sampling to expedite the creation of a database, from where this analysis was derived.

Data collection

The ECRHS survey was conducted in two stages. In stage I, subjects completed a mailed screening questionnaire that collected information about symptoms suggestive of asthma and atopic disease and their treatment. Stage II consisted of a wider interviewer-led questionnaire with 71 items and a medical examination that consisted of determining the total and specific IgE, as well as spirometry and a metacholine challenge test. Data on background factors (sociodemographical factors, living conditions, and parental atopy) were also gathered. At the same time, the MONICA survey including dietary assessment was carried out. Subjects were examined between September 1991 and June 1992. The study protocol obtained approval from the local ethics committee of the Medizinische Akademie, Erfurt, Germany [14, 15].

Study population

Subjects eligible for the study were adults aged 20–64 yrs, who were residents of Erfurt, Germany. The participants were selected randomly from the residential registry. A total of 1,281 subjects who attended the medical examination (Stage II) were invited to participate in the dietary survey. The final study population consisted of 469 males and 333 females, who conducted acceptable dietary protocols and whose measurements of total and specific IgE were available.

Dietary assessment methodology

Data on dietary intake were obtained using prospective 3-day records. Trained nurses instructed the participants in record keeping. Food recording was supported by a combination of accurate weighing with letter scales, portion size estimation with household measures, and a booklet of portion size pictures. The participants completed the food records at home and returned them to the study nurse, who checked it briefly. Food records were rejected if not covering exactly two weekdays and one Sunday or holiday [16–18].

Individual daily food consumption, energy, total fat, and fatty acids were calculated from dietary records using a programme developed in the National Research Centre for Environment and Health based on the German national nutrient data file (Bundeslebensmittelschlüssel II.2) [18, 19]. Although some nutrient calculations were available from previous work, all calculations were repeated with the updated nutrient data file to obtain better quality and consistent information because this data file is constantly being expanded and corrected. Therefore, the dietary data of the current study may not necessarily be identical to the published data that were derived using the preceding Bundeslebensmittelschlüssel II.1.

Food intakes were presented as daily absolute amounts ($g \cdot day$ of consumed $food^{-1}$). Fatty acid intake was computed as amount of the nutrient in grams per 1000 kcal.

Outcome definition

The following outcome variables from the ECRHS were separately considered: asthma, bronchial hyperresponsiveness, allergic sensitisation, reported hay fever, or atopic eczema. Asthma was defined as a positive answer to the question "Have you ever had asthma?" and whether diagnosis was confirmed by a physician.

Methacholine inhalation challenge test was performed using a Mefar MB3 dosimeter (Bovezzi, Italy) in all subjects with a forced expiratory volume >70% of the predicted mean and an absolute value of >1.5 L, who were willing to participate. Bronchial hyperresponsiveness (BHR) was defined as $\geqslant$20% fall in baseline forced expiratory volume in one second before a maximal cumulative dose of methacholine (2 mg) was administered [13, 14]. Allergic sensitisation was assessed by the measurement of specific IgE against common aeroallergens, such as *Dermatophagoides pteronyssinus*, timothy grass, cat allergen, *Cladosporium herbarum*, and birch, using the Pharmacia CAP System (Uppsala, Sweden) [10]. The cut-off to define sensitisation was set at $\geqslant 0.7$ $kU \cdot L^{-1}$ (radioallergosorbent test class $\geqslant$2) from at least one positive specific IgE [10, 13, 14].

Presence of current hay fever as well as life-time atopic eczema was derived from the questionnaire on the basis of a positive answer about those conditions.

Statistical approach

Fat consumption was described using mean, median, SD, and quartiles and stratified by sex. The Wilcoxon Mann-Whitney U-test was applied between the analysed strata. Pearson′s correlation coefficients analysis between consumed fatty acids was presented.

Prevalence of the outcome variables are given. Differences between sex and age groups were determined by Chi-squared test of homogeneity. Subjects were dichotomised according to the presence of allergic disease. Multiple logistic regression were used to analyse the association between food and fatty acids intake and atopic diseases. Odds ratios (OR) and their 95% confidence intervals (95% CI) were computed for the second, third, and highest intake quartiles compared to the first. Linear trends were calculated. Reported ORs were adjusted for age group, social class (defined by educational level), genetic predisposition (parental asthma or atopy), smoking habits, and body mass index.

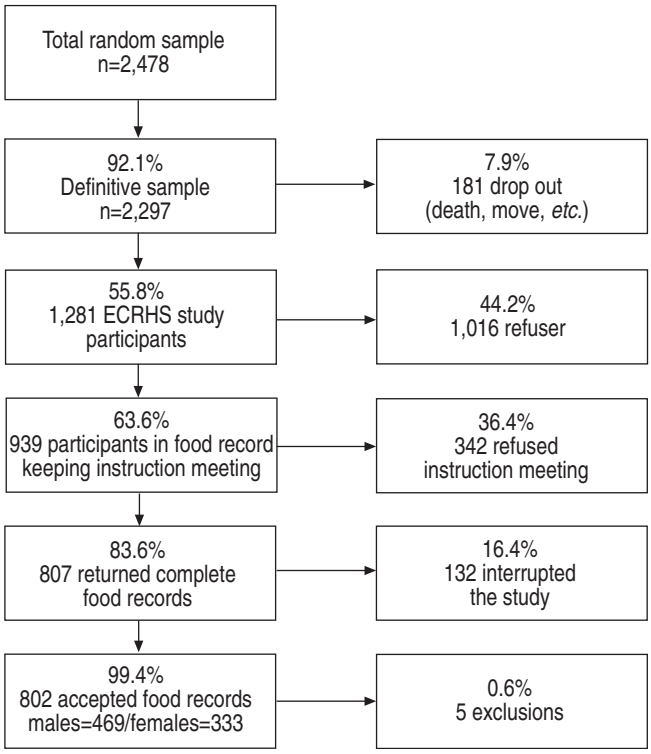

Fig. 1. – Study population. ECRHS: European Community Respiratory Health Survey.

Results

Of the 1,281 subjects who attended the medical examination, 62.6% participated in the dietary survey. Acceptable records on food consumption were obtained from 802 subjects, 63% of whom were male (fig. 1). Metacholine tests for bronchial hyperreactivity was carried out in 613 study participants.

The prevalence of asthma, atopic sensitisation, hay fever, and atopic eczema did not differ between sexes, but the BHR rate was higher in females (table 1). The proportion of study participants aged 40–64 yrs was higher in males. Differences were also observed for all educational levels in which the proportion of males was higher. There was also a higher proportion of male smokers (table 1).

Based on its low prevalence in the study sample (<5%), asthma was classified as an outcome variable (table 1).

Table 1. – Description of the study population

	Total	Males	Females	p-value
Allergic outcomes				
Asthma[#]	26 (3.4)	16 (3.6)	10 (3.1)	0.72
Bronchial hyperresponsiveness[¶]	122 (19.9)	58 (15.8)	64 (26.1)	0.002
Atopic sensitisation[+]	176 (23.1)	102 (23.0)	74 (23.2)	0.95
Hay fever	83 (10.9)	44 (9.9)	39 (12.2)	0.32
Atopic eczema	199 (26.1)	106 (23.9)	93 (29.2)	0.12
Age yrs				
20–40	369 (48.4)	196 (44.2)	173 (54.2)	0.23
41–64	393 (51.6)	247 (55.8)	146 (45.8)	<0.001
Social Class[§]				
<10 yrs	352 (46.2)	210 (47.4)	142 (44.5)	<0.001
10 yrs	238 (31.2)	134 (30.3)	104 (32.6)	0.05
>10 yrs	172 (22.6)	99 (22.4)	73 (22.8)	0.05
Smoking habits				
Smokers	251 (32.9)	161 (36.3)	90 (28.2)	<0.001
Nonsmokers	511 (67.1)	282 (63.7)	229 (71.8)	0.02

Data are presented as n (%) unless otherwise stated. [#]: physician-diagnosed asthma; [¶]: n=613; [+]: defined as at least one specific immunoglobulin E concentration of ≥ 0.7 k $U \cdot L^{-1}$ (radioallergosorbent test class ≥ 2); [§]: defined as the highest achieved educational level in years.

Food consumption

The data on consumption of selected food items and nutrients for males and females indicate a significantly higher absolute butter and margarine intake in males than in females (table 2). In males margarine intake was positively associated

Table 2. – Daily consumption of selected foods and nutrients

	Males					Females					
	Mean	SD	25th percentile	50th percentile	75th percentile	Mean	SD	25th percentile	50th percentile	75th percentile	p-value[+]
Food intake $g \cdot day^{-1}$											
Butter	18	26	1	8	27	12	15	0.5	7	18	<0.001
Margarine	29	23	10	24	41	22	18	9	17	31	<0.001
Vegetable oils	3.6	6.0	0	1.2	4.6	3.2	4.7	0	1.6	4.5	0.30
Fat intake $g \cdot 1000\ kcal^{-1} \cdot day^{-1}$											
Total Fat	45	7	40	45	50	45	7	40	45	49	0.55
SFA	18	4	15	17	20	18	4	15	18	21	0.25
MUFA	17	3	15	17	19	17	3	15	17	19	0.10
PUFA	6.9	2.4	5.1	6.5	8.1	7.1	2.5	5.3	6.8	8.6	0.11
Palmitoleic acid[#]	1.2	0.25	1.0	1.2	1.3	1.2	0.27	0.97	1.2	1.3	0.18
Oleic acid[#]	15	3	13	14	16	14	3	12	14	16	0.10
Linoleic acid[¶]	5.9	2.3	4.3	5.4	7.1	6.1	2.4	4.4	5.7	7.5	0.20
Alpha-Linolenic acid[¶]	0.72	0.28	0.60	0.70	0.80	0.78	0.31	0.65	0.73	0.86	<0.001
Arachidonic acid[¶]	0.10	0.05	0.06	0.08	0.12	0.10	0.07	0.06	0.08	0.12	0.98
Linoleic acid/alpha-Linolenic acid[¶]	8.3	2.8	6.6	7.9	9.4	8.0	3.1	6.2	7.6	9.5	0.07
P:S	0.40	0.18	0.28	0.39	0.52	0.43	0.19	0.31	0.40	0.52	0.49
Omega6:Omega3[¶]	7.6	2.6	5.9	7.3	8.7	7.4	2.7	5.6	6.9	8.6	0.08

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; P:S: polyunsaturated/saturated ratio. [#]: monosaturated fatty acid; [¶]: polyunsaturated fatty acid; [+]: Wilcoxon Mann-Whitney U-test.

Table 3. – Associations between selected food consumption and bronchial hyperresponsiveness (BHR), allergic sensitisation, hay fever and atopic eczema in males

Intake g·day^{-1}	1st quartile	2nd quartile	3rd quartile	4th quartile	p-value
Butter					
BHR	1.00	0.84 (0.36–1.97)	0.79 (0.35–1.80)	0.99 (0.44–2.18)	0.69
Sensitisation	1.00	0.73 (0.38–1.41)	1.06 (0.57–1.96)	0.93 (0.50–1.75)	0.70
Hay fever	1.00	0.79 (0.35–1.75)	0.41 (0.16–1.05)	0.47 (0.19–1.18)	0.09
Atopic eczema	1.00	1.63 (0.87–3.06)	1.25 (0.66–2.37)	0.93 (0.48–1.82)	0.41
Margarine					
BHR	1.00	1.82 (0.82–4.04)	1.28 (0.54–3.04)	0.97 (0.41–2.30)	0.40
Sensitisation	1.00	0.59 (0.31–1.11)	0.62 (0.33–1.17)	0.74 (0.40–1.38)	0.09
Hay fever	1.00	3.23 (1.01–10.35)	3.25 (1.02–10.39)	3.04 (0.95–9.73)	0.03
Atopic eczema	1.00	2.01 (1.07–3.79)	1.53 (0.79–2.99)	1.00 (0.50–1.98)	0.15
Vegetable oils					
BHR	1.00	1.33 (0.53–3.35)	1.08 (0.51–2.30)	1.13 (0.53–2.41)	0.65
Sensitisation	1.00	0.54 (0.25–1.17)	0.65 (0.36–1.15)	0.65 (0.36–1.16)	0.04
Hay fever	1.00	1.59 (0.58–4.34)	1.34 (0.56–3.17)	1.82 (0.80–4.14)	0.20
Atopic eczema	1.00	0.40 (0.17–0.92)	0.61 (0.34–1.10)	0.96 (0.56–1.67)	0.11

Data are presented as adjusted odds ratio, adjusted for age group, educational level, history of parental atopy, smoking habits and body mass index (95% confidence interval) unless otherwise stated. BHR defined as 20% drop in forced expiratory volume in one second during methacholine provocation test; Allergic sensitisation defined as at least one specific immunoglobulin E concentration of $\geqslant$0.7 k U·L^{-1} (radioallergosorbent test class $\geqslant$2). Intake was categorised according to food quartile of daily consumption. N=469, but N=368 for BHR.

with the presence of hay fever but not with atopic sensitisation (table 3). Those associations were not found among females, in whom only high oil intake was positively related to atopic eczema prevalence (table 4). The fish consumption in the analysed sample was too low to assess potential effects (data not shown).

Fatty acids

Fat consumption patterns showed no significant differences between females and males with the exception of alpha-linolenic acid, which was higher in females (table 2). Table 5 shows Pearson's correlation coefficient between consumed fatty acids.

Significant associations between fat intake and health outcomes were mostly limited to females, therefore, tables 6–9 present only the data for female subjects. In males there were no associations between fat intake and prevalence of atopic sensitisation. In females, a high fat intake was positively related to atopic sensitisation (OR 2.42, 95% CI 1.07–5.50) and hay fever (table 7). An increasing trend in the OR for allergic sensitisation was observed with increased intake of saturated and monounsaturated fats (table 7). This association was also found for high intakes of specific monounsaturated fatty acids, such as palmitoleic and oleic acid (OR 3.04, 95% CI 1.26–7.30 and OR 2.47, 95% CI 1.13–5.41, respectively). High intakes of arachidonic acid, an n-6 polyunsaturated fatty acid with pro-inflammatory effects, were associated with allergic sensitisation (OR 2.47, 95% CI 1.07–5.72). Sensitisation prevalence decreased with higher polyunsaturated to saturated fatty acid ratio (OR 0.39, 95% CI 0.18–0.85, p-value 0.01).

In males, a high omega-6 to omega-3 ratio was positively related with hay fever (OR 2.81, 95% CI 1.10–7.16). Table 8 shows associations between fat consumption and hay fever in females. Significant ORs coincide with those reported above for atopic sensitisation. A high intake of total fat, monounsaturated fatty acids and oleic acid consumption were positively linked with hay fever.

Table 4. – Associations between selected food consumption and bronchial hyperresponsivness (BHR), allergic sensitisation, hay fever and atopic eczema in females

Intake g·day^{-1}	1st quartile	2nd quartile	3rd quartile	4th quartile	p-value
Butter					
BHR	1.00	1.27 (0.55–2.93)	1.07 (0.45–2.53)	1.15 (0.49–2.68)	0.68
Sensitisation	1.00	1.08 (0.51–2.27)	0.52 (0.23–1.17)	1.16 (0.55–2.45)	0.70
Hay fever	1.00	0.92 (0.34–2.46)	0.55 (0.20–1.53)	0.94 (0.36–2.46)	0.54
Atopic eczema	1.00	1.43 (0.70–2.89)	1.46 (0.73–2.93)	0.99 (0.48–2.06)	0.40
Margarine					
BHR	1.00	0.78 (0.35–1.76)	0.77 (0.34–1.73)	0.48 (0.20–1.18)	0.27
Sensitisation	1.00	1.00 (0.47–2.13)	0.96 (0.45–2.04)	0.75 (0.34–1.66)	0.75
Hay fever	1.00	1.36 (0.49–3.78)	1.66 (0.62–4.40)	1.25 (0.42–3.68)	0.41
Atopic eczema	1.00	0.79 (0.39–1.58)	1.33 (0.68–2.57)	0.53 (0.25–1.12)	0.60
Vegetable oils					
BHR	1.00	0.93 (0.36–2.41)	1.31 (0.61–2.82)	1.18 (0.55–2.55)	0.62
Sensitisation	1.00	1.07 (0.50–2.32)	0.55 (0.26–1.17)	0.63 (0.30–1.31)	0.20
Hay fever	1.00	0.97 (0.30–3.12)	1.41 (0.56–3.54)	1.59 (0.62–4.09)	0.43
Atopic eczema	1.00	2.12 (1.00–4.46)	1.45 (0.73–2.88)	2.09 (1.06–4.10)	0.04

Data are presented as adjusted odds ratio, adjusted for age group, educational level, history of parental atopy, smoking habits and body mass index (95% confidence interval) unless otherwise stated; BHR defined as 20% drop in forced expiratory volume in one second during methacholine provocation test; Allergic sensitisation defined as at least one specific immunoglobulin E concentration of $\geqslant$0.7 k U·L^{-1} (radioallergosorbent test class $\geqslant$2). Intake was categorised according to food quartile of daily consumption. Total N=333, but only N=245 with BHR data.

Table 5. – Pearson's correlation coefficients between consumed fatty acids stratified for females and males

Males	Total fat	SFA	MUFA	PUFA	Palmitoleic acid	Oleic acid	Linoleic acid	α- Linolenic acid	Arachidonic acid	Linoleic/ α- Linolenic acid	P:S	Omega6/ Omega3	Females
Total fat	1.00	0.77	0.9	0.44	0.74	0.87	0.39	0.34	0.16	0.02	-0.03	0.04	Total fat
		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<0.01	0.66	0.56	0.52	
SFA	0.74	1.00	0.56	-0.15	0.55	0.56	-0.18	0.12	0.08	-0.36	-0.57	-0.34	SFA
	<.0001		<.0001	0.01	<.0001	<.0001	<0.01	0.03	0.13	<.0001	<.0001	<.0001	
MUFA	0.86	0.45	1.00	0.36	0.83	0.95	0.32	0.25	0.18	0.01	-0.02	0.02	MUFA
	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<0.01	0.92	0.67	0.66	
PUFA	0.46	-0.14	0.4	1.00	0.13	0.35	0.98	0.44	0.09	0.65	0.84	0.63	PUFA
	<.0001	<0.01	<.0001		0.02	<.0001	<.0001	<.0001	0.12	<.0001	<.0001	<.0001	
Palmitoleic acid[#]	0.68	0.45	0.8	0.1	1.00	0.71	0.07	0.15	0.3	-0.16	-0.18	-0.2	Palmitoleic acid
	<.0001	<.0001	<.0001	0.03		<.0001	0.19	0.01	<.0001	<0.01	<0.01	<0.01	
Oleic acid[#]	0.85	0.46	0.96	0.38	0.69	1.00	0.33	0.23	0.14	0.05	-0.02	0.09	Oleic acid
	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	0.01	0.4	0.66	0.11	
Linoleic acid[¶]	0.43	-0.15	0.37	0.98	0.05	0.38	1.00	0.34	0.03	0.73	0.85	0.73	Linoleic acid
	<.0001	<0.01	<.0001	<.0001	0.33	<.0001		<.0001	0.6	<.0001	<.0001	<.0001	
α-Linolenic acid[¶]	0.43	0.16	0.34	0.49	0.27	0.3	0.38	1.00	-0.01	-0.23	0.26	-0.21	α-Linolenic acid
	<.0001	<0.01	<.0001	<.0001	<.0001	<.0001	<.0001		0.85	<.0001	<.0001	<0.01	
Arachidonic acid[¶]	0.07	-0.03	0.09	0.1	0.22	0.08	0.05	-0.02	1.00	0.05	0.01	-0.01	Arachidonic acid
	0.14	0.59	0.07	0.03	<.0001	0.08	0.27	0.61		0.33	0.82	0.86	
Linoleic acid/ α-Linolenic acid[¶]	0.06	-0.36	0.08	0.67	-0.2	0.12	0.74	-0.12	0.11	1.00	0.72	0.95	Linoleic acid/ α-Linolenic acid P:S
	0.23	<.0001	0.11	<.0001	<.0001	0.01	<.0001	0.01	0.03		<.0001	<.0001	
P:S	-0.01	-0.56	0.05	0.84	-0.16	0.03	0.82	0.33	0.09	0.69	1.00	0.68	
	0.89	<.0001	0.33	<.0001	<0.01	0.6	<.0001	<.0001	0.07	<.0001		<.0001	
Omega6/ Omega3[¶]	0.09	-0.3	0.12	0.63	-0.21	0.18	0.72	-0.1	0.01	0.94	0.61	1.00	Omega6/ Omega3
	0.05	<.0001	0.01	<.0001	<.0001	<0.01	<.0001	0.04	0.79	<.0001	<.0001		

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; P:S: polyunsaturated to saturated ratio. [#]: monosaturated fatty acid; [¶]: polyunsaturated fatty acid.

A high consumption of the n-3 precursor, alpha-linolenic acid, was negatively associated with atopic eczema, whereas both the linoleic to alpha-linolenic acid ratio and the total omega 6 to omega 3 ratio were significantly related to atopic eczema prevalence (table 9). No association between fat intake and BHR was found (table 6).

Discussion

This study suggests that dietary fat intake is associated with the risk for allergic sensitisation and disease manifestation, with somewhat different findings in males and females. In both males and females, there were indications for an increased risk with a high intake of omega-6 and a low intake of omega-3 fatty acids. In females, total fat and high monounsaturated fatty acids intake were also associated with an increased risk of suffering atopic manifestations. This data adds to the limited epidemiological evidence available on associations between dietary habits and atopic disease prevalence. Most of the published studies were conducted in children, and dietary intake was assessed using simple food item lists, not always well validated. Previous epidemiological studies in Germany used data on the preferred type of spreadable fats on bread as a surrogate for the type of consumed fat and without specific fatty acid determination. The authors did not consider that the total fat intake from the diet may influence the immune response [7–9, 20].

The finding in the current study of a relation of margarine consumption to hay fever prevalence in males, is consistent with the findings from a cross-sectional study conducted in children [7]. Also, results from a Japanese study support the role of PUFA intake, assessed with a food frequency protocol, in the aetiology of seasonal allergic-rhinoconjunctivitis in females. High levels of omega-6 fatty acids may alter the immune response favouring the synthesis of pro-inflammatory mediators, thus enhancing the response to allergens [2]. Moreover, the ratio of omega-6 to omega-3 fatty acids, as well as the supply of the omega-6 metabolite arachidonic acid, was reported to modulate cell membrane composition, gene expression, gut permeability, as well as the activity of the lymphocytes and macrophages, and to enhance IgE production [2, 20–23].

In most published studies, the intake of total and omega 6 PUFA intake was inferred from margarine consumption [1, 2, 7]. Depending on the conditions of its production, margarine is usually a good source of omega 6 PUFA, but often it is also rich in monounsaturated and trans-fatty acids. The potential effect of trans-fatty acids was not analysed in the current study since no reliable information on trans fatty acids was available from the German Food Composition Database. Results from a European ecological study support the hypotheses that a high monounsaturated fatty acids intake might promote the development of allergic sensitisation [10]. Similar effects were found in females, such as an association of specific high IgE concentration with high monounsaturated fatty acids intake, and also with high total fat and saturated fatty acid consumption. Moreover, a positive association was found between the intake of the two major monounsaturated fatty acids, palmitoleic and oleic acids, and to allergic sensitisation. Consistently, a high fat intake, a high monounsaturated fatty acid intake, and specifically a high consumption of oleic acid were also associated with hay fever. Evidence about a positive association between high intake of oleic acid with hay fever has also been shown in a German prospective study [24].

The study was unable to determinate any association between dietary fat, asthma and BHR. The low prevalence of

Table 6. – Associations between dietary intake of fatty acids and bronchial hyperresponsiveness in females

Intake g·1000 Kcal^{-1}·day^{-1}	1st quartile	2nd quartile	3rd quartile	4th quartile	p-value
Total fat	1.00	0.56 (0.24–1.28)	0.54 (0.23–1.29)	0.89 (0.41–1.97)	0.81
SFA	1.00	0.57 (0.24–1.33)	0.72 (0.32–1.63)	0.70 (0.31–1.59)	0.52
MUFA	1.00	0.74 (0.32–1.69)	0.49 (0.21–1.13)	0.73 (0.33–1.61)	0.30
PUFA	1.00	1.20 (0.54–2.66)	0.74 (0.32–1.72)	0.74 (0.32–1.75)	0.32
Palmitoleic acid[#]	1.00	0.64 (0.28–1.42)	0.37 (0.16–0.89)	0.72 (0.32–1.64)	0.26
Oleic acid[#]	1.00	0.55 (0.24–1.28)	0.63 (0.28–1.43)	0.62 (0.28–1.40)	0.31
Linoleic acid[¶]	1.00	1.68 (0.75–3.75)	1.03 (0.44–2.40)	0.73 (0.30–1.76)	0.30
Alpha-Linolenic acid[¶]	1.00	0.80 (0.34–1.87)	0.88 (0.39–1.96)	1.00 (0.44–2.29)	0.97
Arachidonic acid[¶]	1.00	1.34 (0.60–3.02)	0.68 (0.28–1.62)	1.12 (0.48–2.60)	0.81
Linoleic acid/Alpha-Linolenic[¶]	1.00	1.62 (0.73–3.60)	0.55 (0.23–1.36)	0.94 (0.41–2.15)	0.48
P:S	1.00	1.37 (0.63–2.99)	0.88 (0.38–2.06)	0.54 (0.23–1.29)	0.11
Omega6/Omega3[¶]	1.00	1.87 (0.83–4.22)	0.51 (0.21–1.27)	0.95 (0.41–2.16)	0.33

Data are presented as adjusted odds ratio, adjusted for age group, educational level, history of parental atopy, smoking habits and body mass index (95% confidence interval) unless otherwise stated. Intake was categorised according to nutrient quartile of daily consumption; Bronchial hyperresponsiveness was defined as a 20% drop in forced expiratory volume in one second during the methacholine provocation test. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; P:S: polyunsaturated to saturated ratio. [#]: monosaturated fatty acid; [¶]: polyunsaturated fatty acid.

Table 7. – Associations between dietary intake of fatty acids and allergic sensitisation[+] in females

Intake g·1000 Kcal^{-1}·day^{-1}	1st quartile	2nd quartile	3rd quartile	4th quartile	p-value
Total fat	1.00	2.52 (1.12–5.68)	1.56 (0.66–3.64)	2.42 (1.07–5.50)	0.12
SFA	1.00	1.18 (0.51–2.76)	2.35 (1.07–5.17)	1.99 (0.89–4.46)	0.03
MUFA	1.00	0.84 (0.36–1.99)	1.81 (0.83–3.94)	2.13 (0.98–4.62)	0.02
PUFA	1.00	1.12 (0.54–2.34)	0.86 (0.40–1.85)	0.69 (0.32–1.51)	0.28
Palmitoleic acid[#]	1.00	3.01 (1.29–7.02)	2.86 (1.19–6.85)	3.04 (1.26–7.30)	0.02
Oleic acid[#]	1.00	1.44 (0.63–3.30)	1.52 (0.68–3.43)	2.47 (1.13–5.41)	0.03
Linoleic acid[¶]	1.00	1.42 (0.67–3.02)	1.45 (0.68–3.08)	0.70 (0.31–1.60)	0.47
Alpha-Linolenic acid[¶]	1.00	0.65 (0.30–1.43)	1.12 (0.53–2.36)	0.94 (0.45–1.98)	0.81
Arachidonic acid[¶]	1.00	2.59 (1.16–5.77)	1.97 (0.85–4.58)	2.47 (1.07–5.72)	0.08
Linoleic acid/Alpha-Linolenic[¶]	1.00	1.09 (0.52–2.24)	0.92 (0.44–1.93)	0.52 (0.23–1.17)	0.12
P:S	1.00	0.70 (0.34–1.44)	0.51 (0.24–1.09)	0.39 (0.18–0.85)	0.01
Omega6/Omega3[¶]	1.00	0.80 (0.37–1.72)	1.22 (0.59–2.53)	0.57 (0.26–1.28)	0.36

Data are presented as adjusted odds ratio, adjusted for age group, educational level, history of parental atopy, smoking habits and body mass index (95% confidence interval) unless otherwise stated. Intake was categorised according to nutrient quartile of daily consumption. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; P:S: polyunsaturated to saturated ratio. [#]: monosaturated fatty acid; [¶]: polyunsaturated fatty acid; [+]: defined as at least one specific immunoglobulin E concentration of $\geqslant$0.7 kU·L^{-1} (radioallergosorbent test class $\geqslant$2).

self-reported doctor's diagnosis of asthma in the study sample impeded the application of a multiple statistical test. Additionally, the lack of significant associations between BHR and fatty acid intake may be related to the reduced number of participants on the methacholine provocation test, thus causing a loss of statistical power.

Most statistically significant effects in relation to fat consumption and allergic disease in the current study were

Table 8. – Associations between dietary intake of fatty acids and hay fever in females

Intake g·1000 Kcal^{-1}·day^{-1}	1st quartile	2nd quartile	3rd quartile	4th quartile	p-value
Total fat	1.00	3.14 (0.95–10.35)	1.28 (0.34–4.81)	4.51 (1.38–14.75)	0.05
SFA	1.00	2.83 (0.84–9.53)	1.93 (0.55–6.75)	3.13 (0.95–10.28)	0.13
MUFA	1.00	0.94 (0.29–3.03)	1.62 (0.54–4.90)	3.04 (1.07–8.59)	0.01
PUFA	1.00	0.90 (0.33–2.48)	1.10 (0.40–3.03)	1.58 (0.60–4.14)	0.31
Palmitoleic acid[#]	1.00	1.31 (0.43–3.93)	1.57 (0.52–4.71)	2.75 (0.94–8.00)	0.06
Oleic acid[#]	1.00	2.60 (0.76–8.84)	2.36 (0.67–8.28)	4.99 (1.53–16.32)	0.01
Linoleic acid[¶]	1.00	1.08 (0.38–3.08)	1.54 (0.55–4.30)	1.97 (0.73–5.35)	0.14
Alpha-Linolenic acid[¶]	1.00	0.84 (0.27–2.63)	1.93 (0.70–5.33)	1.53 (0.53–4.40)	0.21
Arachidonic acid[¶]	1.00	0.99 (0.37–2.60)	0.94 (0.34–2.62)	1.22 (0.46–3.21)	0.72
Linoleic acid/Alpha-Linolenic acid[¶]	1.00	1.42 (0.53–3.82)	1.39 (0.50–3.83)	1.37 (0.49–3.83)	0.58
P:S	1.00	1.07 (0.42–2.74)	0.58 (0.19–1.72)	1.16 (0.45–2.94)	0.97
Omega6/Omega3[¶]	1.00	1.79 (0.62–5.12)	1.53 (0.51–4.58)	2.38 (0.83–6.81)	0.15

Data are presented as adjusted odds ratio, adjusted for age group, educational level, history of parental atopy, smoking habits and body mass index (95% confidence interval) unless otherwise stated. Intake was categorised according to nutrient quartile of daily consumption. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; P:S ratio: polyunsaturated to saturated ratio. [#]: monosaturated fatty acid; [¶]: polyunsaturated fatty acid.

Table 9. – Associations between dietary intake of fatty acids and atopic eczema in females

Intake g·1000 Kcal^{-1}·day^{-1}	1st quartile	2nd quartile	3rd quartile	4th quartile	p-value
Total fat	1.00	1.18 (0.59–2.35)	1.01 (0.50–2.03)	0.98 (0.49–1.98)	0.85
SFA	1.00	1.04 (0.50–2.14)	1.62 (0.81–3.24)	1.08 (0.53–2.21)	0.55
MUFA	1.00	1.12 (0.56–2.24)	0.88 (0.43–1.80)	1.19 (0.60–2.38)	0.79
PUFA	1.00	0.88 (0.44–1.74)	0.84 (0.42–1.69)	0.82 (0.41–1.64)	0.57
Palmitoleic acid[#]	1.00	1.12 (0.55–2.30)	1.75 (0.87–3.50)	1.07 (0.52–2.21)	0.57
Oleic acid[#]	1.00	0.81 (0.40–1.64)	0.94 (0.47–1.88)	1.04 (0.52–2.08)	0.82
Linoleic acid[¶]	1.00	1.16 (0.59–2.30)	0.75 (0.36–1.53)	1.02 (0.51–2.04)	0.75
Alpha-Linolenic acid[¶]	1.00	0.98 (0.50–1.91)	0.77 (0.38–1.54)	0.47 (0.22–0.98)	0.04
Arachidonic acid[¶]	1.00	2.01 (1.01–4.02)	1.10 (0.53–2.28)	1.19 (0.57–2.47)	0.91
Linoleic acid/Alpha-Linolenic[¶]	1.00	1.09 (0.52–2.29)	1.79 (0.88–3.65)	1.95 (0.96–3.98)	0.03
P:S	1.00	1.57 (0.78–3.19)	2.19 (1.08–4.45)	0.80 (0.37–1.72)	0.82
Omega6/Omega3[¶]	1.00	1.36 (0.65–2.85)	1.74 (0.84–3.59)	2.02 (0.98–4.15)	0.04

Data are presented as adjusted odds ratio, adjusted for age group, educational level, history of parental atopy, smoking habits and body mass index (95% confidence interval) unless otherwise stated. Intake was categorised according to nutrient quartile of daily consumption; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; P:S ratio: polyunsaturated to saturated ratio. [#]: monosaturated fatty acid; [¶]: polyunsaturated fatty acid.

limited to females. Sex-specific dietary patterns might partly explain the observed differences. In the current study, significantly higher absolute butter and margarine intakes in males were observed, but other allergy linked dietary factors were not analysed [25]. In addition, the development of atopic diseases may underlie different sex-linked physiological mechanisms. Furthermore, the lower participation rate in females may have induced bias.

The authors did not consider alcohol consumption as confounder, which is markedly higher in males and might enhance oxidative stress and modulate immune responses [16–19, 26]. As another potential covariable, a decreased fruit and vegetable consumption with a low intake of antioxidants was suggested to be associated with recent increases in asthma [25, 27]. The possible modulating role of the intestinal microflora, the dietary intake of non-digestible carbohydrates that serve as substrates for colonic bacteria, and of intestinal trophic factors has received increased attention following indications that administration of specific lactobacilli in early life may reduce the risk of atopic dermatitis [28]. Thus, the effect of dietary components other than fat intake on the immune response needs to be considered in further evaluations.

Given the large number of associations tested in the current study, some of the founded effects may be due to chance. However, the authors hypothesise that consistency across outcomes measurements, such as atopic sensitisation and hay fever, and independent effects observed between highly correlated fatty acids intake and atopy outcomes, reflect a valid pattern of associations.

Based on the results of the current study and previously published results, the authors hypothesise that an excess of fat or imbalance in fat intake, particularly of monounsaturated fatty acids, could alter immune function and increase the risk of an allergic reaction. This data cannot demonstrate a causal association between fat consumption and atopy, in which case diet would be a modifiable risk factor and dietary manipulation might serve as a useful tool in public health programmes oriented to prevent and treat allergic disease. Prospective intervention trials would offer an opportunity to investigate these hypotheses, which hold a great potential for health prevention strategies.

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