

ORIGINAL ARTICLE

Fat intake and asthma in Spanish schoolchildren

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Objectives: To study the relationship between lipid, fatty acid and lipid-rich food intake and current asthma in a group of Spanish schoolchildren.

Subjects/Methods: The subjects of this cross-sectional study were 638 Spanish schoolchildren (8–13 years of age). The weight and height of all the subjects were recorded. A questionnaire, completed by the subjects' parents, was used to obtain personal and health information. Current asthma was established when the children had ever had asthma, if they had been diagnosed with asthma by a doctor and if they had been treated with medications at some time in the previous 12 months. Food intake was monitored using a 3-day food record. All foods consumed were converted into energy and nutrients.

Results: The energy derived from lipids, saturated fatty acids (SFAs) and myristic and palmitic acids was independently associated with current asthma (Odds Ratio (OR) third tertile 2.85 (1.01–8.07) $P=0.049$, 10.00 (0.89–111.97) $P=0.002$, 11.21 (1.36–92.24) $P=0.002$, 7.58 (1.40–41.03) $P=0.022$, respectively), as was the intake of butter (OR third tertile 2.97 (1.01–8.68) $P=0.001$). No relationship was seen between this condition and the intake of any other fatty acid, the n-6/n-3 ratio, nor the consumption of margarine, milk products, fish, meat, eggs or vegetable oils.

Conclusions: Increased intakes of SFAs, myristic and palmitic acids and butter seem to be related to the risk of current asthma in children.

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Keywords: fat intake; fatty acids; butter; asthma; children

Introduction

In recent years there has been an increase in the prevalence of asthma. This cannot be explained by genetic changes, and many studies searching for environmental causes have been undertaken (Bush and Peden, 2009; Von Mutius, 2009).

There is evidence that the consumption of fruits and vegetables prevents the development of asthma, as consequence of their containing antioxidants, such as vitamins C and E, beta-carotene and flavonoids (Fogarty and Britton, 2000; Kim *et al.*, 2009). Furthermore, the change in diet in developed countries towards an increased consumption of proteins and lipids and a reduction in the consumption of carbohydrates could also be involved (Wood and Gibson, 2009).

However, although some authors report an association between the intake of lipids, certain fatty acids and certain

foods and asthma (Bolte *et al.*, 2005; Laerum *et al.*, 2007; Olsen *et al.*, 2008), others have found none (Devereux and Seaton, 2005; Almqvist *et al.*, 2007; Kim *et al.*, 2009; de Vries and Howie, 2009). Nevertheless, because of the fact that saturated fatty acids (SFAs) intake among children is very high nowadays, reaching the double of the recommended intake in some cases (Royo-Bordonada *et al.*, 2006; McNeill *et al.*, 2010), SFAs intake could be related to the increase in the prevalence of asthma.

The aim of the present work was to study the relationship between lipids, fatty acids and lipid-rich foods intake and current asthma in a group of Spanish schoolchildren.

Materials and methods

Sample recruitment

The study subjects were 638 schoolchildren aged between 8 and 13 years who attended 14 schools in the Madrid region of Spain. The directors were contacted by phone to arrange an interview during which the characteristics and the importance

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of the study were explained. Permission was requested to meet the parents of the children in the 8–13 years age group. Once permission was given, the parents were explained about the details of the study and all their questions were answered. Signed permission was then sought to include their children in the study. All subjects took part voluntarily.

The exclusion criteria were as follows:

- A lack of authorization to take part or the non-acceptance of any of the conditions required for the study to proceed.
- Non-attendance on days when tests or interviews were performed.
- Having a pathology that might modify the results, alter food habits (and therefore nutrient intake) or recommended non-inclusion

The study was approved by the Human Research Review Committee of the Pharmacy Faculty, Complutense University of Madrid.

Health survey

The subjects' parents answered a questionnaire designed to provide information on their children's health. Information was collected on subject age, smoking habit of the parents, whether the subjects were breast fed (and for how long), any background of asthma or other disease and any medications taken.

To establish the diagnosis of current asthma, parents were asked if their children ever had asthma, if their children had been diagnosed with asthma by a doctor and if their children had had an episode of asthma or an asthma attack during the past 12 months. These questions have been used by Sistek *et al.*, 2001 to define current asthma in adults. In the present study, the final diagnosis of current asthma was established when a positive response was given to the first two questions (Sistek *et al.*, 2001) and, according with Miyamoto *et al.* (2007), when children had been treated with medications at some time in the previous 12 months. Furthermore, the diagnostic approach was supervised and confirmed by a Pulmonologist.

Anthropometric survey

All measurements were made at the schools in the morning and following norms set out by the World Health Organization (WHO, 1995).

Weight and height were determined using a digital electronic balance (Seca Alpha, GmbH Igni, France) (range 0.1–150 kg, precision 100 g) and a Harpenden digital stadiometer (Pfifter, Carlstadt, NJ, USA) (range 70–205 cm, precision 1 mm) respectively. For these measurements, subjects were barefoot and wore only underwear. Subject body mass index was calculated as weight (kg)/height² (m²).

Dietary survey

A '3-day dietary record' was followed for three consecutive days including a Sunday (from Sunday to Tuesday) (Ortega *et al.*, 2006). Parents were instructed to record the weights, if

possible, and to record household measurements (spoonfuls, cups and so on), if not, of all food consumed outside school by their children. Trained researchers visited the school canteen on Monday and Tuesday to record the menu served to students, the amounts of food served to each child and amounts leftover.

Energy and nutrient intakes were calculated using food composition tables (Department of Nutrition, 2004a). The values obtained were compared with those recommended (Department of Nutrition, 2004b) to determine the adequacy of the diets. Special attention was paid to the intake of lipids, fatty acids and lipid-rich foods. DIAL software was used to process all data (Department of Nutrition and Alce Ingeniería, 2009).

Theoretical energy expenditure was established by taking into account the body weight, age and physical activity of all children, using equations proposed by the Institute of Medicine (2005).

To validate the results of the dietetic study, energy intake was compared with the theoretical energy expenditure. The percentage discrepancy between the energy intake and the sum of the measured and declared intakes was determined using the following formula:

$$\frac{(\text{Theoretical energy expenditure} - \text{energy intake}) \times 100}{\text{theoretical energy expenditure}}$$

A negative value indicates the declared energy intake to be greater than the theoretical energy expenditure (probable overestimation), whereas a positive value indicates it to be lower than the theoretical energy expenditure (probable underestimation) (Ortega *et al.*, 1995).

Statistical analysis

Means and s.d.s. were calculated for all variables. One-way ANOVA was used to identify significant differences between children with and without current asthma. Comparisons between proportions were performed using the χ^2 -test. Nutrient and food intake was divided into tertiles. Multiple logistic regression was used to explore the relationship between the prevalence of current asthma and intake of lipid, fatty acids and lipid-rich foods, adjusting for confounding factors, such as energy intake, fat intake, age, gender, body mass index, parental history of asthma, atopic eczema and allergic rhinitis and parental cigarette smoking. All calculations were made using RSIGMA BABEL Software (Horus Hardward, Madrid, Spain). Significance was set at $P < 0.05$.

Results

The current asthma prevalence was 4.4% of the entire group of 638 subjects (28 subjects) who participated at this survey.

No significant differences were seen between those with and without this condition in terms of age, anthropometric

Table 1 Characteristics of the study subjects with and without asthma (X ± s.d.)

	Without asthma	Asthma
<i>n</i>	610	28
Age (years)	10.7 ± 0.9	10.6 ± 0.9
Weight (kg)	39.2 ± 9.7	40.6 ± 11.0
Height (m)	1.43 ± 0.09	1.44 ± 0.08
BMI (Kg/m ²)	18.9 ± 3.3	19.4 ± 4.2
Sex		
Boys (%)	45.2	63
Girls (%)	54.8	37
Family background (%)	4.75	10.71
Parents' smoking habit (%)	21.5	16
Maternal smoking habit (%)	35.5	29.6
Existence of breastfeeding (%)	80.7	67.9
Breastfeeding duration (months)	5.8 ± 4.6	7.7 ± 6.2

Abbreviation: BMI: body mass index.

One-way ANOVA was used to identify significant differences between children with and without asthma.

characteristics, first-degree family member background of asthma, parental smoking habits or having been breast fed (Table 1).

However, the daily energy derived from lipids, SFAs and myristic acid was higher among those with asthma (Table 2).

None of the lipid-rich food was consumed in significantly greater quantities by those with asthma (Table 3).

Table 4 shows the Odds Ratios (ORs) and 95% confidence intervals (95%CI) for the prevalence of asthma with respect to the intake of lipids, of the different types of fatty acids studied and of lipid-rich foods above the third and below the first tertiles. Subjects in whom the energy derived from lipids, SFAs and myristic and palmitic acids was above third tertile were at 2.85, 10.00, 11.21 and 7.58 times more likely to have current asthma than those whose consumptions were below the first tertile (Table 4).

Subjects who consumed > 5.3 g per day of butter were 2.97 times more likely to suffer from current asthma than those whose intake was < 2.5 g per day (Table 4). It should be noted, however, that the higher intake of butter by the children with asthma did not, in fact, reach significance (Table 3).

Discussion

The prevalence of asthma found in the present study is lower than the prevalence reported in other European countries as Norway, where the prevalence was 11.1% in 10 year-old children (Lødrup Carlsen *et al.*, 2006), Portugal, where the prevalence was 12.9% in 13-year-old children (Falcão *et al.*, 2008), Greece, where the prevalence was 9.0% and 5.0% at 7 and 18 years, respectively (Bacopoulou *et al.*, 2009), or France, where the prevalence among children between 11 and 14 years was 9% (Delmas *et al.*, 2009). Nevertheless, our

Table 2 Characteristics of the diet of children with and without current asthma (X ± s.d.)

	Without asthma	Asthma
Energy (kcal per day)	2142 ± 351	2190 ± 385
Discrepancy intake/ expenditure (%)	−3.42 ± 21.78	0.23 ± 20.70
<i>Energy profile</i>		
Carbohydrates (% energy)	40.66 ± 4.90	38.79 ± 5.68
Proteins (% energy)	15.61 ± 2.24	15.13 ± 2.20
Lipids (% energy)	42.16 ± 4.68**	44.68 ± 4.53**
<i>Lipid profile</i>		
SFAs (% energy)	14.60 ± 2.17**	15.80 ± 2.43**
MUFAs (% energy)	17.31 ± 2.78	18.60 ± 2.43
PUFAs (% energy)	6.90 ± 1.84	6.85 ± 2.03
<i>SFAs (% energy)</i>		
C14:0 Myristic	1.21 ± 0.37*	1.38 ± 0.40*
C 16:0 Palmitic	7.54 ± 1.21	8.00 ± 1.36
C 18:0 Stearic	3.24 ± 0.61	3.39 ± 0.77
<i>MUFAs (% energy)</i>		
C 16:1 Palmitoleic	0.71 ± 0.15	0.73 ± 0.18
C 18:1 Oleic	15.78 ± 2.72	17.02 ± 2.41
<i>PUFAs (% energy)</i>		
C 18:2 Linoleic	6.12 ± 1.80	6.04 ± 2.05
C 18: 3 Linolenic	0.44 ± 0.14	0.46 ± 0.15
C 20:4 Arachidonic	0.06 ± 0.04	0.05 ± 0.03
C 20:5 Eicosapentaenoic	0.03 ± 0.05	0.04 ± 0.09
C 22:5 Docosapentanoic	0.01 ± 0.01	0.01 ± 0.01
C 22:6 Docosahexanoic	0.06 ± 0.07	0.08 ± 0.13
n3 Polyunsaturated fatty acids (g per day)	0.21 ± 0.10	0.25 ± 0.12
n6 Polyunsaturated fatty acids (g per day)	8.0 ± 3.7	8.0 ± 5.1
n6/ n3 Ratio	43.5 ± 32.5	39.7 ± 41.3

Abbreviations: MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; SFAs, saturated fatty acids.

One-way ANOVA was used to identify significant differences between children with and without asthma. **P* < 0.05; ***P* < 0.01.

Table 3 Consumption of different foods (g per day) by children with and without asthma (X ± s.d.)

	Without asthma	Asthma
Meat	170.3 ± 79.9	163.0 ± 81.6
Fish	48.3 ± 46.9	44.4 ± 43.8
Eggs	33.0 ± 21.2	30.3 ± 23.0
Dairy and dairy products	482.0 ± 176.0	534.1 ± 172.1
Vegetable oils	28.0 ± 9.75	31.8 ± 11.0
Butter	3.05 ± 5.05	5.01 ± 6.26
Margarine	1.05 ± 3.30	0.01 ± 0.08

One-way ANOVA was used to identify significant differences between children with and without asthma.

results are more proximal to the prevalence found in Sweden children (5.9%) from 5–14 years old (Kim *et al.*, 2005), Dutch children (6.5%), who had the same range age than children studied in our study (8–13 years) (Tabak *et al.*, 2006) or

Table 4 Factors associated with the suffering from current asthma

	First tertile	Third tertile	Adjusted OR (95% CI)
Fats (% energy)	40.3	44.3	2.85 (1.01–8.07); <i>P</i> = 0.049
SFAs (% energy)	13.7	15.5	10.00 (0.89–111.97); <i>P</i> = 0.002
C14:0 Myristic (% energy)	1.0	1.3	11.21 (1.36–92.24); <i>P</i> = 0.002
C 16:0 Palmitic (% energy)	7.0	8.0	7.58 (1.40–41.03); <i>P</i> = 0.022
C 18:0 Stearic (% energy)	3.0	3.4	1.38 (0.35–5.48); <i>P</i> = 0.114
MUFAs (% energy)	16.1	18.3	1.07 (0.03–41.53); <i>P</i> = 0.051
C 16:1 Palmitoleic (% energy)	0.64	0.76	0.57 (0.84–0.68); <i>P</i> = 0.329
C 18:1 Oleic (% energy)	14.5	16.8	1.28 (0.09–17.33); <i>P</i> = 0.156
PUFAs (% energy)	5.9	7.5	0.45 (0.13–1.61); <i>P</i> = 0.229
C 18:2 Linoleic (% energy)	5.1	6.8	0.40 (0.12–1.36); <i>P</i> = 0.107
C 18: 3 Linolenic (% energy)	0.38	0.45	1.11 (0.35–3.52); <i>P</i> = 0.260
C 20:4 Arachidonic (% energy)	0.035	0.067	0.55 (0.12–2.58); <i>P</i> = 0.143
C 20:5 Eicosapentaenoic (% energy)	0.002	0.018	1.45 (0.48–4.37); <i>P</i> = 0.082
C 22:5 Docosapentaenoic (% energy)	0.007	0.015	0.78 (0.23–2.63); <i>P</i> = 0.298
C 22:6 Docosahexanoic (% energy)	0.027	0.058	1.15 (0.40–3.32); <i>P</i> = 0.792
n3 Polyunsaturated fatty acids (g per day)	0.16	0.23	0.81 (0.22–3.01); <i>P</i> = 0.759
n6 Polyunsaturated fatty acids (g per day)	5.7	8.9	0.85 (0.29–2.44); <i>P</i> = 0.118
n6/ n3 Ratio	27.4	46.9	0.86 (0.28–2.64); <i>P</i> = 0.259
Meat (g per day)	126	192.5	1.02 (0.25–4.15); <i>P</i> = 0.647
Fish (g per day)	18.7	59.8	1.22 (0.38–3.98); <i>P</i> = 0.162
Eggs (g per day)	21	39.7	0.35 (0.11–1.05); <i>P</i> = 0.062
Dairy and dairy products (g per day)	397	535	2.62 (0.66–10.44); <i>P</i> = 0.166
Vegetable oils (g per day)	23	31.5	0.65 (0.19–2.30); <i>P</i> = 0.508
Butter (g per day)	2.5	5.3	2.97 (1.01–8.68); <i>P</i> = 0.001
Margarine (g per day)	5	9	0.45 (0.07–2.76); <i>P</i> = 0.390

Abbreviations: MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; SFAs, saturated fatty acids.

Italian children (6.7%) who were 6–7 years old (Corbo *et al.*, 2008). When our results are compared with other Spanish studies (the present study was carried out in Madrid, which is in the middle of Spain), the prevalence is lower than in other regions (for example, Barcelona: 8.5%, Valencia: 9.3%), but

especially when it is compared with zones near the north coast (for example, A Coruña: 12.9%; Bilbao: 12.2%) (Carvajal-Ureña *et al.*, 2005). In this respect, milder climate and high humidity have been shown to be risk factors for asthma (García-Marcos *et al.*, 2009). The low asthma prevalence observed in our study could be explained by the rising prevalence of medication use in symptomatic children over time, that may reflect better asthma control (Mommers *et al.*, 2005; Quirce, 2009).

This is the first study to investigate the relationship between lipids, fatty acids and lipid-rich foods intake and the risk of current asthma in Spanish schoolchildren.

A number of studies have explored the possible relationship between lipids, fatty acids and lipid-rich foods intake and asthma, but the results obtained have been conflicting (de Vries and Howie, 2009). Some authors have reported an association between the increase in asthma and atopic disease and the increase in n-6 polyunsaturated fatty acids (PUFAs) (from margarine and vegetable oils) and decrease in n-3 PUFA (from fish) consumption. A possible explanation of these findings could be that these fatty acids are involved in immune and inflammatory processes (Mermer and Mercola, 2002; Devereux and Seaton, 2005; Tabak *et al.*, 2006). n-6 PUFAs (especially linoleic acid) and vegetable oils can be metabolized to arachidonic acid, the precursor of prostaglandins and proinflammatory leukotrienes. In contrast, n-3 PUFAs, such as eicosapentaenoic acid and docosahexanoic acid, reduce the production of these inflammatory mediators (Stulnig, 2003). In the present study, no relationship was found between the intake of these fatty acids and current asthma (Tables 3 and 4). It is in agreement with other studies that did not find an association between PUFA intake and the risk of asthma (Nagel and Linseisen, 2005; Miyamoto *et al.*, 2007; Miyake *et al.*, 2008). For example, in a study of 1002 pregnant Japanese women, it was observed that neither the intake of n-3 nor n-6 fatty acids was related to the risk of current asthma. Nonetheless, an association was found with the n-3/n-6 PUFA ratio. The women with ratios above the third tertile (>0.2218) were less likely to suffer current asthma than those with a ratio below the third tertile (<0.1914) (OR = 0.26 (0.05–0.93); *P* = 0.03) (Miyamoto *et al.*, 2007). However, Miyake *et al.* (2008) found no association between the intake of linoleic acid, alpha-linolenic acid, arachidonic acid, eicosapentaenoic acid, docosahexanoic acid or the n-6/n-3 PUFA ratio and suffering from asthma in a study of 25 033 Japanese schoolchildren aged 6–15 years. Neither did Nagel and Linseisen (2005) find any association between the intake of these fatty acids and current asthma in a group of 525 German adults. However, they did find an increase in adult-onset asthma with dietary intake of the monounsaturated fatty acid (MUFA) oleic acid, relating this to the consumption of margarine, which was also a risk factor. It should be noted that, unlike that reported by Nagel and Linseisen, 2005, in the present work either oleic acid intake or margarine consumption was not associated with an increased risk of current asthma.

Regarding MUFAs intake and asthma, Heinrich *et al.* (2001) after adjusting for energy intake, observed the intake of MUFAs to be positively related to the prevalence of atopic disease. However, in a Taiwanese study involving 1166 adolescents, MUFA intake was found to be inversely proportional to asthma (OR=0.65 (0.43–0.99)) (Huang and Pan, 2001). This discrepancy might be explained by the smaller quantities of MUFAs provided by the Taiwanese diet compared with that of Europeans, with an excess of these fatty acids being responsible for allergic sensitization and asthma. In the present study, among children with asthma, some 8.2% consumed more MUFAs than recommended (recommended intake=sufficient to provide 18% of energy needs) and 2.6% consumed less than recommended ($P<0.05$), which is according with the theory that excess of MUFAs intake could be related with asthma.

Fewer studies have explored the link between SFAs and the risk of asthma, but most of those that have reported a positive association to exist (for example, de Luis *et al.*, 2003). In fact, the first evidence suggested that the increase in asthma in developed countries could (at least in part) be due to a diet rich in PUFAs and poor in SFAs (Black and Sharpe, 1997). However, in the above study by Huang and Pan, 2001, the intake of SFAs was clearly associated with an increased risk (OR=2.02, 95%CI 1.40–2.90). Similarly, in a study involving 54 Spanish asthma patients (age 23.6 ± 9.6 years), the mean SFAs intake (covering 18.4% of energy needs) was found to be significantly higher than that recommended (<7%). These results agree with those of the present study, in which it was found that SFAs covered more of the energy intake than recommended and were associated with current asthma (Tables 2 and 4). The effects of these fatty acids could be owed to their mediation of inflammation by the direct activation of toll-like receptor 4, which sets in motion an NF κ B-driven inflammatory cascade (Wood and Gibson, 2009), and to the activation of protein kinase C and mitogen-activated protein kinases, which induce the expression of inflammatory genes in immune cells (Kennedy *et al.*, 2009).

However, closer analysis revealed that, among the SFAs ingested, daily energy derived from myristic and palmitic acids was associated with current asthma (Tables 2 and 4). One of the main source of these fatty acids is butter, which also showed an association with current asthma (Table 4). This result contrasts with that of a Swedish study involving 1014 schoolchildren (age 5–14 years), in which the associations between allergens and respiratory symptoms were more pronounced among those who did not consume butter and who had a low intake of milk (Kim *et al.*, 2005). A similar observation was recorded in the Prevention and Incidence of Asthma and Mite Allergy birth cohort study (2003); after following 2978 pre-school children in the Netherlands for one year, the prevalence of recent asthma and wheezing was found to be lower in children who consumed butter daily than in those who did not (1.5 vs 5.1% for asthma and 7.7 vs

15.4% for wheezing) (Wijga *et al.*, 2003). The authors of the latter study suggested that butter consumption increased the proportion of saturated fat in the diet and reduced that of unsaturated fat, and that a reduced proportion of linoleic acid in the diet might impede the development of asthma. However, they could provide no direct evidence for this. In contrast, and in line with the results of the present study, Takaoka and Norback (2008) reported butter consumption to be a risk factor for wheezing in their study of 153 Japanese female university students. The reasons for such a discrepancy are unclear.

Certainly, butter consumption has been linked to breast cancer, atherosclerosis and cataract (Tavani *et al.*, 1996; Mikkilä *et al.*, 2009; Pala *et al.*, 2009) probably because of its SFAs content. For example, when SFAs has been replaced with polyunsaturated fat, a reduction in low-density lipoprotein cholesterol and a reduction in coronary heart disease risk have been observed (Woodside *et al.*, 2008); and postmenopausal women with an intake of SFAs >15% of total energy intake presented a 7% higher mammary density than postmenopausal women consuming <15% of SFAs of total energy intake (Nagata *et al.*, 2005). The mechanism is not clear, but according with these studies, and in the same way, an excess in SFAs intake could also be linked to asthma.

The present study suffers the limitation of being cross-sectional in nature; no causal relationships can, therefore, be inferred from the results. It would be interesting to conduct prospective studies in which subjects were examined at specific intervals.

Other possible limitation of the study is that a 3-day dietary record was chosen in the dietary survey. A major disadvantage of the dietary record method is that it is subject to bias both in the selection of the sample and in the measurement of the diet. Dietary record keeping requires that respondents be both motivated and literate (if carried out on paper), which can potentially limit use of the method in some population groups (for example, those of low socioeconomic status, the poorly educated, recent immigrants, children and some elderly groups) (Thompson and Subar, 2008). For this reason, parents recorded the dietary records instead of children and to clarify entries and to probe for forgotten foods, a trained interviewer reviewed the records with parents at the end of the recording period. Furthermore, a 3-day dietary record was chosen and not a food frequency questionnaire because some studies have shown that some frequency questionnaires agree weakly to moderately with the 3-day diet records and resulted in consistently higher intakes of all nutrients when they are applied in children (Wilson and Lewis, 2004; Fumagalli *et al.*, 2008).

In conclusion, it would appear that diets in which the proportion of the energy intake derived from lipids, especially saturated fats, is high, are linked to the suffering from current asthma in children. In particular, a high intake of myristic and palmitic acids or of butter (the main source of these fatty acids), seems to be linked to this problem.

Conflict of interest

The authors declare no conflict of interest.

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