

Dietary intake in adolescents with asthma – potential for improvement

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Associations between an unhealthy diet and overweight and the presence of asthma are reported. The aims of this study were to assess whether the intake of nutrients and food items in adolescents with asthma differs from that of healthy adolescents, whether the intake was in accordance with the Nordic Nutrition Recommendations (NNR) or whether possible relationships were confounded by body composition. A four-day-validated 18-page pre-coded food diary was completed by 169 13- to 14-year-old adolescents, 93 with asthma and 76 healthy control subjects, in addition to clinical assessment, anthropometric measurements, lung function and skin prick tests. Neither intake of added sugar, snacks nor saturated fat was associated with asthma. All groups had an intake of saturated fat and added sugars exceeding the NNR, while the intake of fruits and vegetables, fibre and vitamin D was lower than recommended. The intake of folate, calcium, magnesium and iron was lower than recommended for girls with asthma and healthy girls. The intake of vitamin C was satisfactory for all groups. Body composition did not influence eating habits, and the prevalence of overweight was similar in the two groups. The dietary intake among Norwegian adolescents in general had a potential for improvement. As girls have a lower energy intake than boys, they have a larger demand of quality of the diet. Additional dietary research in adolescents with asthma is recommended.

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The high prevalence of childhood asthma in “western societies” (1–3) cannot be explained by genetic background alone and is thus likely to be associated with environment as well as lifestyle. Less physical activity and a dietary change may contribute to the recent increase in asthma and atopy, although teenagers with asthma in the Oslo Environment and Childhood Asthma (ECA) study were as physically active as those without asthma (4).

Dietary vitamin C intake or serum ascorbate concentration has been associated with asthma (5–7), suggesting that patients with asthma have low supplies of vitamin C or an increased demand for this vitamin. Hijazi et al. (8) reported eating at fast food outlets as a significant risk factor for wheezy illness in 12-year-old children.

A Norwegian dietary study including 4-, 9- and 13-year-old children (9) showed a higher intake of added sugars than recommended in the Nordic Nutrition Recommendations (NNR) (10) with a negative influence on the intakes of micronutrients, fruits and vegetables (9). Soft drinks contributed to the highest proportion of added sugars, in line with the general increase in consumption of added sugars (11). The consumption of soft drinks has been positively associated with obesity in a 19-month follow-up among 11- to 12-year-old children (12), whereas obesity and overweight (with varying definitions) have been implicated in asthma in several studies (13, 14). Several mechanisms for the relationship between overweight and asthma have been proposed, including mechanical, immunological,

hormonal and inflammatory effects of overweight (14). However, detailed studies of dietary nutrients to explain the observed associations between overweight and asthma are largely lacking.

The main objective of this study was to examine whether nutrients and food items intake was associated with asthma in adolescents, focusing on the intake of fruits and vegetables, soft drinks, sweets and snacks. The secondary objective was to assess the intakes of macro- and micronutrients in relationship to the NNR (10) and to examine whether possible relationships between nutrient intake and asthma were confounded by overweight.

Subjects and methods

Study design and subjects

This study has a nested case-control 13-year follow-up design (4) in the ECA study in Oslo (15). The adolescents were identified at 10 yr as children with current asthma (cases) and without a history of asthma (controls). At 13 yr, they were reassessed and reclassified according to the same criteria as at 10 yr (3, 4). Of the 310 invited adolescents (147 adolescents with current asthma and 163 controls), 174 attended the 13-year follow-up study (65% of adolescents with asthma and 49% of the controls). One hundred and sixty-nine adolescents completed the food diaries and are included in the final analysis.

The participating adolescents were similar to those who did not attend the 10-year follow-up study with respect to socioeconomic factors, BMI, lung function, bronchial hyper-responsiveness, use of inhaled corticosteroids or β -2 agonist, prevalence of wheeze- and exercise-induced bronchoconstriction. Only the food-recording results will be discussed in relation to asthma in the present study.

The study was approved by the Medical Research Ethics Committee and the Data Inspectorate of Norway. Written informed consent was obtained from the participating children and their parents.

Methods

This study included a parental *structured interview* (4) including central International Study of Asthma and Allergies in Childhood questions related to airways symptoms (validated in Norwegian language (16)) of the child, in addition to detailed questions of medication use, lifestyle and diseases (3).

Skin prick tests to common inhalant and food allergens were performed in 10-year follow-up ECA study (3) with the following fresh allergen dilutions for milk and otherwise Soluprick® allergens (ALK Abello, Hørsholm, Denmark): domestic mites (*Dermatophagoides* (D.) *pteronissinus* and *D. farinae*), German cockroach, dog, cat and rabbit dander, birch, timothy (grass) and mugwort pollens, mould (*Cladosporium* herbarium and *Alternaria alternata*), egg white, milk, peanut and codfish. Sensitization was considered positive with a wheal diameter ≥ 3 mm larger than the negative control (NaCl) (3).

Forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC) and forced expiratory flow at 50% of FVC (FEF_{50}) were measured, described elsewhere (4).

Subjects were *weighed* wearing light clothing and without shoes to the nearest 0.1 kg (Seca 709, Hamburg, Germany). *Height* was measured to the nearest 0.5 cm by using a stadiometer. The *waist circumference* was measured to midway between the costal arch and the iliac crest with a metal anthropometric tape to the nearest 0.5 cm at the end of a gentle expiration. *Skinfold thicknesses* were measured with a Harpenden fat caliper at the biceps, triceps, subscapular and suprailiac region. *BMI* (body weight in kilograms/square of height in metres) was calculated for each participant. Overweight and obesity were defined according to Cole et al. (17).

The entire *food intake* was registered using an 18-page pre-coded food diary mainly by the participants themselves for 4 consecutive days, 3 weekdays and 1 weekend day [starting on a Wednesday or on a Sunday (random order)] by all participants (9, 18). The dietary method is standardized and validated for adolescents (18). An instruction video demonstrating how to complete the food diaries and written additional information was given to the participants before food registration started. The adolescents received an short message service reminder the morning the registration started. The project dietician phoned them the second evening of the registration period to answer questions and to encourage completion of the registration, which was subsequently returned by mail. The diary contained lists of 277 drinks, food items and dishes, grouped together according to a typical Norwegian diet (9). Each group was supplemented with open-ended alternatives. Food amounts were presented in pre-defined household units or as portions estimated from photographs in a photographic booklet (9). The photographic booklet with 13 colour photograph

series, each with four different portion photographs, was previously found for portion size estimates in children and adolescents aged 9-19 (19).

Daily intake of foods, energy and nutrients was computed using a food database and software system developed at the Department of Nutrition, University of Oslo, Norway (KBS version 4.9). The food database was mainly based on the official Norwegian food composition table, which is continuously supplemented with data on new food items and nutrient contents. Added sugar was calculated by refined or industrially produced sugars used as an ingredient in processed or prepared food (9). The use of cod liver oil and vitamin and mineral supplements was included in the nutrient calculation.

The reference values for nutrient intake were based upon the Nordic Nutrition Recommendations (10) for adolescents. The recommended intake of fruits and vegetables for adolescents in Norway is 500 g/day (20).

A comparison of energy intakes with estimates of basal metabolic rate was used to calculate the number of respondents who underreported their energy intake. Goldberg's cut-off values (21) are usually used to evaluate whether reported energy intakes are a plausible measure of the food consumed during an actual measurement period.

Statistical analysis

Demographic data are given as mean values and standard deviation (SD) unless otherwise stated and results as mean with 95% confidence intervals (CI). Chi-square tests or independent t-test was used to analyse differences between groups.

Differences in outcome variables between groups were assessed by analysis of covariance adjusting for age and gender. The underlying assumptions of the analysis of covariance were assessed using Jack-knife Residuals and Cook's d. The dependent variables, fruits and vegetables, sugar/sweets, soft drinks with sugar and snacks, as well as waist circumference, skinfolds, age and gender, were analysed for associations with asthma using logistic regression analysis. Level of significance was set to 5%. The analyses were performed with SPSS version 15.0 (SPSS, Chicago, IL, USA).

Results

Among the 169 adolescents (103 boys) in this study, 93 were defined with asthma whereas 76 had never had asthma. A positive skin prick test was more prevalent in the adolescents with

Table 1. Descriptive data of the participating adolescents presented by asthma and controls

	Asthma (n = 93)	Controls (n = 76)	p value**
Age (years); Mean (Min–Max)*	13.6 (12.7–14.3)	13.6 (12.6–14.3)	0.89
Body mass (kg)	53.4 (10.8)	50.5 (9.7)	0.07
Height (cm)	163.8 (9.1)	162.0 (7.1)	0.16
BMI (kg/m ²)	19.7 (2.9)	19.2 (3.0)	0.20
Waist circumference (cm)	74.2 (9.9)	72.0 (6.9)	0.09
Sum of skinfolds (mm)	37.7 (13.1)	36.1 (12.8)	0.45
Overweight, % (n)*	16.1 (15)	10.5 (8)	0.48
Positive skin prick test, % (n)*	49.5 (46)	22.7 (17)	0.02
FEV ₁ (% of predicted)	99.9 (12.6)	104.2 (12.7)	0.03
FEF ₅₀ (% of predicted)	86.2 (21.0)	98.7 (22.0)	<0.001
FEV ₁ /FVC	84.5 (6.7)	87.5 (6.0)	0.003

FEV₁, Forced Expiratory Volume after 1 s; FVC, Forced Vital Capacity; FEF₅₀, Forced Expiratory Flow at 50% of FVC; Min, Minimum; Max, Maximum.

*Data are given as mean and s.d. in parentheses unless otherwise stated.

**p values for any differences between groups.

Statistically significant values are given in bold.

asthma (Table 1) and more often in boys. Adolescents with asthma had significantly lower FEV₁, FEF₅₀ (% of predicted) and FEV₁/FVC compared to controls (Table 1). With respect to body mass and height, the adolescents with asthma did not differ significantly from the controls (Table 1).

Food items

Intake of fruits and vegetables (including potatoes, berries and fruit juices) (Table 2) was lower than recommended, among both adolescents with asthma and control subjects. The intake of snacks, soft drinks and sugar/sweets did not differ significantly between the two groups. However, boys (both with and without asthma)

Table 2. Adjusted* daily intake of selected food items in 13-year-olds with and without asthma

	Asthma (n = 93)	Controls (n = 76)	p value**
Fruits and vegetables (g)†	299 (252, 347)	339 (288, 389)	0.27
Sugar/sweets (g)	34 (27, 42)	37 (29, 45)	0.59
Soft drinks with sugar (g)‡	254 (207, 302)	198 (148, 248)	0.11
Diet soft drinks (g)	153 (101, 205)	113 (57, 168)	0.29
Snacks (g)	9 (6, 12)	6 (3, 10)	0.29

*Adjusted for age and gender. Data are given as mean (95% CI).

**p values for any differences between groups.

†Fruits and vegetables includes vegetables, potatoes (fresh), fruits, berries and fruit juices.

‡Soft drinks includes sweetened carbonated soft drinks and other sweetened soft drinks, i.e. lemonade and iced tea (diet soft drinks are artificially sweetened soft drinks).

Table 3. Daily intake of energy and nutrients in adolescents with asthma and control subjects (supplements included) in comparison with Nordic Nutrition Recommendations (NNR)

	Asthma boys (n = 65)	Control boys (n = 38)	NNR*	Asthma girls (n = 28)	Control girls (n = 38)
Energy (MJ)	9.0 (8.4–9.7)	9.0 (8.2–9.7)	–	7.6 (6.6–8.5)	7.7 (7.2–8.2)
Protein (E%)	16.2 (15.5–16.8)	15.2 (14.5–16.0)	10–20	14.3 (13.2–15.3)	14.3 (13.2–15.3)
Fat (E%)	32.6 (31.4–33.8)	31.2 (29.5–32.9)	25–35	31.4 (29.6–33.2)	31.9 (30.3–33.5)
Saturated fat (E%)	14.0 (13.4–14.6)	13.8 (13.0–14.7)	<10	14.0 (13.1–14.9)	14.0 (13.2–14.8)
Monounsaturated fat (E%)	10.8 (10.3–11.4)	10.3 (9.6–10.9)	10–15	10.1 (9.3–10.9)	10.2 (9.6–10.9)
Polyunsaturated fat (E%)	5.4 (5.1–5.8)	4.9 (4.4–5.3)	5–10	5.1 (4.6–5.7)	5.3 (4.9–5.7)
Carbohydrate (E%)	51.3 (49.9–52.6)	53.5 (51.5–55.5)	50–60	54.2 (52.0–56.4)	52.7 (51.0–54.4)
Added sugars (E%)	12.6 (11.0–14.2)	14.8 (13.3–16.4)	≤ 10	16.5 (13.9–19.0)	12.6 (11.2–14.1)
Fibre (g)	17.0 (14.1–19.8)	17.1 (14.0–20.2)	25–35	13.8 (11.2–16.4)	15.0 (13.7–17.8)
Retinol equivalent (μg)	1082 (901–1263)	1075 (883–1267)	600	1064 (726–1402)	1230 (1012–1449)
α-Tocopherol (μg)	9.9 (8.4–11.5)	8.8 (7.5–10.2)	7 (8)†	9.6 (6.9–12.3)	10.2 (8.5–11.9)
Vitamin D (μg)	5.0 (3.8–6.1)	4.1 (3.0–5.3)	7.5	5.5 (2.9–8.1)	5.9 (4.2–7.5)
Thiamin (mg)	1.3 (1.1–1.5)	1.2 (1.0–1.3)	1.0 (1.2)†	1.2 (0.9–1.5)	1.2 (1.0–1.5)
Riboflavin (mg)	1.7 (1.5–1.9)	1.5 (1.4–1.7)	1.2 (1.4)†	1.5 (1.1–1.8)	1.5 (1.3–1.8)
Folate (μg)	211 (181–241)	192 (173–212)	200	180 (148–213)	197 (172–221)
Vitamin C (mg)	97 (80–115)	91 (76–106)	50	96 (74–119)	98 (74–122)
Calcium (mg)	944 (826–1061)	952 (848–1055)	900	785 (700–869)	727 (613–841)
Iron (mg)	12.1 (10.2–13.9)	11.1 (9.6–12.6)	11	9.7 (8.0–11.4)	9.9 (8.9–11.4)
Magnesium (mg)	281 (251–310)	279 (245–312)	280	225 (197–253)	246 (224–268)

Mean (95% CI).

*Nordic Nutrition Recommendations 2004 (10).

†Values for boys in parenthesis.

had a significantly higher intake of soft drinks and snacks compared to girls (e.g. boys with asthma had a mean intake of 295 (228, 362) g soft drinks and 13 (8, 19) g snacks while the girls with asthma had a mean intake of 217 (139, 295) g soft drinks and 4 (1, 8) g snacks).

Intake of sugar/sweets, fruits/vegetables and snacks was not associated with asthma. Intake of soft drinks with sugar was associated with asthma ($p = 0.04$); however, this association was no longer significant after adjusting for gender. The results were not confounded by waist circumference or skinfolds.

Energy and nutrients

Energy intake was similar in all groups (Table 3). The percentage of boys with asthma underreporting their energy intake was 23.1%, for their controls it was 18.4%. For girls with asthma, the percentage was 25.0% while for the controls 18.4%.

The intake of macro- and micronutrients was similar in all groups, except for added sugars. Boys with asthma and healthy girls had the lowest mean intake of added sugars (12.6 (11.0, 14.2) E% and 12.6 (11.2, 14.1) E%), while girls with asthma had the opposite (16.5 (13.9, 19.0) E%). The intake in healthy boys was 14.8 (13.3, 16.4) E%.

Intake in relation to Nordic Nutrition Recommendations

All groups had a higher E% from saturated fat than recommended in the NNR while the E% of polyunsaturated fat was in the lower level of the recommended range (Table 3). The E% of added sugars was above the recommended intake for all groups. The intake of fibre was lower than recommended for all adolescents. Mean intakes of micronutrients, apart from vitamin D, calcium (girls), folate (girls), iron (girls) and magnesium (girls), were covered compared with current recommendations.

Discussion

The nutritional intake was not significantly different in adolescents with and without asthma. In general, the adolescents had a lower intake of fruits and vegetables, fibre, vitamin D and polyunsaturated fat than recommended (i.e. polyunsaturated fat is in the lower level of the recommended range). The intake of calcium, folate, iron and magnesium was lower than recommended in girls, both overall and in the asthma group specifically. The E% of saturated fat and added sugars was above the recommended level for all adolescents.

The similar nutritional intake among adolescents with and without asthma is in agreement

with Murray et al. (22). There was no difference between the intake of fruits and vegetables among adolescents with asthma and healthy controls in line with Tabak et al. (23). In a study from Saudi Arabia, the consumption of vegetables was significantly lower in children with a history of asthma or wheeze in the last 12 months (8). Others have shown a positive association between frequency of fresh fruit consumption and lung function and that low intakes of vitamin A, C, E were associated with reduced lung function (7). It is, however, difficult to compare these studies, because they, for example, vary in how asthma/wheeze is defined and in how the dietary recordings are made. Some suggest that intervention studies based on dietary advice to increase the intake of fruits and vegetables are needed, including standardized lung function measures (8).

It is known that there is a marked increase in overweight among Norwegian adolescents (24) and that they have a high E% of added sugars and a low intake of fruits and vegetables (9). Similar findings in adolescents with asthma in this study might be a marker of an unhealthy lifestyle in other aspects, e.g. reduced physical activity. Some studies have reported decreased activity among children with a diagnosis of asthma (25, 26) while the results from Berntsen et al. (4) did not confirm this findings. A study on oral health in preschool children with asthma showed that sugar-containing drinks were consumed more frequently in the children with asthma (27); however, in the analysis, gender was not taken into account. With a lower percentage of obese children in our population as well as a generally lower energy intake, the results support the importance of encouraging children to increase their levels of physical activity and not to overeat.

To our knowledge, no other studies have used a similar method to record food intake (four-day recording using food diaries) in adolescents with asthma. The method used in this study has been validated in 13-year-old adolescents (18). Food frequency questionnaire (FFQ) is the most common method used in dietary research. Another study among children with asthma concludes that in-depth analysis of food intake based on daily diaries should be used in future dietary research (28), as in this study. The percentage of underreporting (according to "Goldberg factor") is relatively high, but not unlike other dietary surveys using the same method (18). Tabak et al. (23) used an FFQ developed for adults and claimed that non-validated questions and questionnaires were used to assess dietary intake in

most studies on diet and asthma in childhood. Underreporting of energy is influenced by body weight, with obese subjects more likely than normal weight subjects to underreport energy intake (29). Being less time-consuming is the advantage of using a pre-coded diary compared with traditional methods like weighed records, 24-hour recall and dietary history (18). Interviewed adolescents found it easy to fill in the food diary with 10–15 min daily required to complete the diary (18). A validation study showed that the photographic booklet is a useful tool for portion size estimates in this age group (19). In this study, the adolescents also found it simple to register their data. They hardly ever had questions when they were contacted the second day in the registration period.

Øverby et al. (9) showed a negative association between a high intake of added sugar and the intake of fruits and vegetables and micronutrients. The consumption of soft drinks and snacks in dietary studies is probably higher than reported (30). Food items considered unhealthy and snacks between the meals are most likely to be underreported. In this study, the intake of soft drinks, sweets and snacks is therefore probably higher. This underreporting results in a lower energy intake than actually consumed, which is supported by the relatively high percentage of underreporting that was calculated in this study, 18–25%. It is common that self-reported dietary data often results in underreporting of energy intake (31). Low motivation and issues surrounding body image may also influence dietary reporting in adolescence (18). Adolescents also have unstructured eating patterns with frequent out-of-home eating, lacking knowledge and limited interest about food and food preparation techniques (32, 33). As the percentage of underreporters with asthma and control subjects is on the same level, the relatively high percentage of underestimation is of less importance for comparisons between the groups.

Strengths and limitations of this study

The adolescents in this study were recruited from a general population-based birth cohort with careful clinical assessment and definition of asthma (3) and a detailed food and nutrient registration at the same time as physical activity was objectively recorded. Furthermore, the asthma definition is strengthened by previously demonstrated associations with current (3) and previous (34) lung function as well as genetic factors (35).

A limitation of this study is the chance that significant differences may not be found because of a relatively small population sample. However, other studies of similar (22, 36) or larger size (8, 28) were in line with our findings, deeming our negative results less likely to be because of a type II error.

Conclusion

Norwegian adolescents with and without asthma had similar food, energy, nutrient and fruit/vegetable intake, with lower than recommended intake of fruits and vegetables, fibre and vitamin D and a higher than recommended intake of saturated fat and added sugars.

Boys had a higher intake of sugar-containing soft drinks than girls, and girls had a lower intake of folate, calcium, iron and magnesium than recommended. This study suggests that there is a potential for improvement of the diet for the groups included. There is a demand for additional dietary research in adolescents with asthma.

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Conflict of interest

The authors are not aware of any conflict of interest.

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