

Nutrition and Asthma

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Abstract Over the past four decades, the prevalence of asthma has markedly increased in Westernized countries and countries transitioning to this lifestyle. It has been hypothesized that these increases are a consequence of changing environmental and/or behavioral factors. The modification of dietary habits (ie, decreased intake of fruits/vegetables and increased intake of “Westernized” processed foods) and a decrease in sun exposure have led to decreased intake of antioxidant vitamins and fatty acids and to decreased circulating levels of vitamin D, and have been proposed to explain the rise in asthma prevalence. This article summarizes the main findings on foods and nutrients connected to asthma based on several exhaustive recent reviews on the topic, and examines the evidence for an effect of dietary patterns on asthma. Overall, findings underscore the importance of conducting prospective studies and clinical trials to better understand the role of diet in the etiology of asthma.

Keywords Diet · Asthma · Wheeze · Antenatal diet · Childhood diet · Adulthood diet · Nutrition · Childhood asthma · Adulthood asthma · Vitamin A · Vitamin C · Vitamin E · Selenium · Zinc · Fruits · Vegetables · Omega-3 · Fish · Vitamin D · Dietary patterns · Diet score · Mediterranean diet score · Alternate Healthy Eating Index

Introduction

Over the past four decades, the prevalence of asthma has markedly increased in Westernized countries, and it has been hypothesized that these increases are a consequence of changing environmental and/or behavioral factors [1]. Along these lines, the modification of dietary habits (ie, decreased intake of fruits and vegetables and increased intake of “Westernized” processed foods) paralleled the increase in asthma, but to date, there has been more attention paid to diet associated with other chronic diseases, such as cardiovascular disease and cancer. It has been hypothesized that the increase in asthma prevalence may be due to changing antioxidant intake, increasing dietary ratio of n-6 to n-3 polyunsaturated fatty acids (PUFAs), and vitamin D deficiency [2•].

Several hypotheses have been raised regarding the role of diet in asthma over the life course. In recent years, studies have reported associations between childhood asthma and maternal diet during pregnancy and/or childhood dietary intake [2•, 3•, 4•, 5, 6•]. Epidemiologic and immunologic studies suggest that dietary modification or supplementation in the fetal life could reduce the development of atopic diseases, while fetal undernutrition could detrimentally affect the “programming” of the fetal lung and immune system [5]. Early-life diet could modulate the likelihood of childhood asthma by affecting fetal airway development and/or influencing the initial early-life interactions between allergens and the immune system [5].

However, all the published studies on respiratory diseases and diet are very heterogeneous regarding exposure assessment (food frequency questionnaires, 24-hour recall, biomarkers), phenotype (asthma, wheeze), window of exposure (antenatal, childhood diet, adulthood diet), or study design (case-control, cross-sectional, longitudinal), and very few randomized clinical trials have been published [2•, 3•, 4•, 5, 6•, 7, 8]. Therefore, all these studies are somehow inconclusive.

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Studying dietary patterns instead of specific foods or nutrients is a new approach in nutritional epidemiology of chronic diseases to assess the effects of overall diet [9]. This approach has been used to investigate the role of diet in several chronic diseases, but few studies have been conducted on asthma. An overall approach of dietary patterns could provide some insight on the combinations of foods and/or nutrients that might be beneficial or detrimental to asthma prevalence, severity, and control.

Several exhaustive reviews were recently published (2009–2011) regarding foods and nutrients connected to asthma [2•, 3•, 4•, 5, 6•, 7–9]. However, little attention has been paid to dietary patterns associated with asthma. The first part of the present paper summarizes the main findings on foods and nutrients, while the second part presents detailed recent findings regarding dietary patterns.

Foods and Nutrients Connected to Asthma

Recent reviews have been published regarding foods and nutrients connected to asthma [2•, 3•, 4•, 5, 6•, 7–9]. The main findings are summarized in Table 1. The major nutrients and/or foods studied are dietary antioxidant intakes, PUFA intakes, and more recently, vitamin D intake.

Dietary Antioxidant Intake

Asthma is an inflammatory disease of the airways, and endogenous reactive oxygen species have been implicated in its pathogenesis. Different antioxidants may have different mechanisms through which they might protect lung tissue against oxidative damage. Vitamin E, a lipid-soluble vitamin, represents the body's principal defense against oxidant-induced membrane injury by serving as a major

scavenger of free radicals in the lipid phase [10]; the main dietary sources of vitamin E are seed oils and nuts. Vitamin C, a water-soluble vitamin, is responsible for maintaining the antioxidant capacity in the aqueous phase and also contributes to the regeneration of membrane-bound oxidized vitamin E [10]; the main dietary sources of vitamin C are fruits and vegetables. Likewise, vitamin A and provitamin A carotenoids such as α -carotene, β -carotene, β -cryptoxanthin, lutein/zeaxanthin, and lycopene have antioxidant properties [10]; the main dietary sources of carotenoids are fruits and vegetables. Selenium is incorporated into the antioxidant enzyme glutathione peroxidase, which reduces hydrogen peroxide and other organic peroxides, thereby preventing lipid peroxidation and subsequent instability of cell membranes [10]; the main dietary sources of selenium are seeds, seafood, and fish. Zinc, an essential trace element that exists in all cells and is required by thousands of proteins for catalytic, structural, or transcriptional functions, could act as an antioxidant [11]; the main dietary sources of zinc are oysters, beef, and certain types of seafood.

Regarding antenatal diet, a small number of cohort studies have highlighted associations between childhood asthma and reduced maternal intake of vitamin E, zinc, and fruits and vegetables during pregnancy [2•, 3•]; no randomized controlled trials (RCTs) have been published. Regarding the childhood period, the association between asthma and diet is weak overall but nonetheless suggestive in relation to vitamins A and E and zinc. The highest level of evidence comes from the beneficial intake of fruits and vegetables during childhood [3•]. Neither longitudinal studies nor RCTs have been published. Among adults, observational studies have reported associations between asthma and vitamin E, vitamin C, carotenoids, selenium, polyphenols, and fruits and vegetables [2•]. Several RCTs have been conducted, but they do not support the use of vitamin C, vitamin E, or

Table 1 Main findings regarding the associations between foods and nutrients with asthma or wheeze

	Maternal diet during pregnancy		Diet in childhood			Diet in adulthood		
	Longitudinal	Intervention	Cross-sectional or case-control	Longitudinal	Intervention	Cross-sectional or case-control	Longitudinal	Intervention
Vitamin E	+	?	+	?	?	+/-	+	x
Vitamin C	x	?	x	?	?	+	x	x
Vitamin A	x	?	+	?	?	+	?	?
Selenium	+/-	?	x	?	?	+	?	x
Zinc	+	?	+	?	?	?	?	?
Fruits and Vegetables	+	?	++	?	?	++	++	?
PUFA (n-3, n-6)	+	+/-	+	?	x	+	x	+/-
Vitamin D	+/-	?	?	+	-	+	?	?

?, no study; x, no association; +/-, inconclusive findings; +, suggestive beneficial effect; ++, conclusive beneficial effect; -, suggestive deleterious effect; <5, based on <5 studies; ≥ 5 , based on at least 5 studies; PUFA, polyunsaturated fatty acid

selenium supplements to complement conventional therapy for asthma [2••]. Overall, the body of observational evidence is inherently weak because of the biases and limitations of the cross-sectional and case-control studies that predominate.

Dietary Polyunsaturated Fatty Acid Intake

The intake of specific fatty acids also has been proposed as an etiologic factor in asthma [2••, 7, 8]. It has been hypothesized that the increased intake of n-6 PUFAs (present in spread oils and oils sourced from vegetables) and the decreased intake of n-3 PUFAs (present in oily fish such as salmon and mackerel) in Western countries have strongly contributed to the rise in asthma prevalence. Linoleic acid (an unsaturated n-6 fatty acid) is in the production pathway of several prostanoids and leukotrienes active in bronchoconstriction and neutrophil chemotaxis [12]. By contrast, n-3 PUFAs compete with arachidonic acid to form less active metabolites, and may thereby reduce airway inflammation and bronchoconstriction [12].

Regarding antenatal and childhood diet, several studies have related dietary PUFA intake to childhood asthma [2••]. However, there is a need for well-conducted RCTs [2••, 7, 8]. Among adults, observational studies have reported associations between asthma and PUFAs. However, these findings were not confirmed in cohort studies, and supplementing the diet of adults with asthma with n-3 PUFAs has minimal, if any, clinical benefit [2••].

Vitamin D

Vitamin D intake represents a combination of dietary intake of vitamin D (eg, fortified milk) and vitamin D synthesized in the skin upon exposure to UVB radiation from sunlight. This unique situation has perhaps hindered research on the relation of overall vitamin D intake to risk of chronic disease. There are several emerging mechanisms by which vitamin D may affect asthma, including 1) vitamin D effects on airway smooth muscle modulation of gene expression and chemokine secretion, leading to decreased alveolar smooth muscle proliferation and decreased airway inflammation, two effects that might prevent or improve airway obstruction; 2) vitamin D-mediated reversal of steroid resistance; and 3) improved handling of respiratory infections, leading to decreased asthma exacerbation [13•].

Studies from birth cohorts regarding the association between maternal dietary intake of vitamin D during pregnancy and wheeze and asthma have yielded conflicting results [2••, 3••]. A recent study in a New Zealand cohort showed that low levels of cord blood vitamin D concentrations were associated with higher risk of respiratory infections at 3 months, but not with incident asthma at 5 years [14••]. A more recent study in Spain also confirmed this finding and reported that higher maternal circulating vitamin D

concentrations in pregnancy were independently associated with lower risk of lower respiratory tract infections in offspring in the first year of life, whereas no association was reported with the risk of wheezing or asthma in childhood [15••]. The protective effect of vitamin D on respiratory infections may play a role in the development and exacerbation of asthma. Among children, previous studies of vitamin D levels and expression of asthma phenotypes have concentrated on children already diagnosed with asthma, and reported that low levels of vitamin D were associated with worse asthma control and with asthma severity [16]. Up to now, only one longitudinal study has been conducted in Australia, and it reported that vitamin D levels at ages 6 and 14 years were predictive of allergy phenotypes at that age, but not asthma. More importantly, vitamin D levels at age 6 years were predictive of subsequent asthma and atopy phenotypes at age 14 years [17]. One RCT has been published using data from the Northern Finland Birth Cohort 1966 and reported that large-dose vitamin D supplementation in infancy was associated with an increased risk of atopy, allergic rhinitis, and asthma later in life (age 31 years) [18]. Among adults, few studies have been conducted. A recent study conducted in the NHANES 2005–2006 reported a strong protective effect of vitamin D against wheeze and asthma exacerbation, supporting the notion that vitamin D status might influence the risk of respiratory disease [19••].

Taken together, these findings underscore the importance of conducting prospective studies and clinical trials to better understand the role of antioxidants, n-3 PUFAs, and vitamin D in asthma and wheeze in children and adults.

Dietary Patterns and Asthma

Assessment of Dietary Pattern and Methodologic Issues

Diet is a complex exposure variable. Several approaches have been proposed in nutritional epidemiology to address this issue. Traditional analyses in nutritional epidemiology typically study the development of diseases in relation to a single or a few nutrients or foods. However, these traditional analyses have faced several conceptual and methodologic challenges [9]. People do not consume isolated nutrients, but rather meals consisting of a variety of foods with complex combinations of nutrients. Some nutrients are also highly correlated, making it difficult to examine their separate effects when they are entered into a model simultaneously. Also, when a large number of foods or nutrients are tested, multiple associations are tested and significant results may appear only by chance (multiple testing not taking into account).

To address these issues, several authors have proposed studying overall diet by considering how foods and nutrients

are consumed in combinations [9]. In dietary pattern analysis, the collinearity of nutrients and foods could be used to advantage because patterns are characterized based on similarity of habitual food use. Examination of dietary patterns would parallel more closely the real world, in which dietary intakes consist of nutrients that are found together in common foods. Classifying individuals according to their overall eating pattern can yield a larger contrast between exposure groups than analyses based on single nutrients. Dietary pattern analyses are particularly relevant for diseases such as asthma, in which no specific foods or nutrients have been clearly identified.

Two general approaches have been used to define these summary variables in observational studies. The so-called *a posteriori* approach, built on statistical exploratory methods (eg, exploratory factor analysis and cluster analysis), works well in identifying the major dietary patterns of a particular study population but independently of their relevance to any disease. The *a priori* approach focuses on the calculation of a score that describes an ideal diet with a disease-specific focus, building on previous knowledge concerning the health effects of various dietary components or even of entire diets.

A variety of dietary indices (*a priori* approach) have been proposed. The most widely used is probably the Mediterranean diet score. The original score was proposed in 1995 by Trichopoulos et al. [20] and was based on the consumption of eight components (high monounsaturated to saturated fat ratio; moderate ethanol consumption; high consumption of legumes, cereals, fruits, and vegetables; and low consumptions of meat/meat products and of milk/dairy products). For each component, the median value for each sex was used as a cutoff point; therefore, the score ranged from 0 to 8. These scores evolved constantly to take into account new knowledge in nutritional epidemiology. The Mediterranean score was modified several times, first to include high consumption of fish [21], then to remove potatoes and bread from the cereals component in order to take into account only whole grain cereals instead of all cereals, or to add a high consumption of nuts [22]. Because alcohol consumption is not recommended for pregnant women, the Mediterranean score has also been adapted among pregnant women by removing the alcohol component [23•]. Based on similar considerations, the KIDMED score (Mediterranean Diet Quality Index in children and adolescents) was derived to be applied among children [24]. The Alternate Healthy Eating Index (AHEI), a measure of diet quality based on modified recommendations from the US Department of Agriculture, was originally designed to provide dietary guidelines in an effort to decrease the prevalence of major chronic diseases [25]. Briefly, the AHEI was based on nine components: vegetables, fruit, nuts and soy, the ratio of white (seafood and poultry) to red meat, cereal fiber, trans fat, the ratio of

PUFAs to saturated fatty acids, long-term multivitamin use (<5 or ≥5 years), and alcohol consumption. Each component had the potential to contribute 0 to 10 points to the total score, with the exception of multivitamin use, which contributed either 2.5 or 7.5 points. All the component scores were summed to obtain a total AHEI score, which ranged from 2.5 to 87.5, with a higher score representing a healthier diet [25]. The AHEI also has been modified for pregnancy (AHEI-P) [26].

The most recent studies (2009–2011) relating dietary patterns, derived either *a priori* or *a posteriori*, to asthma or wheeze are presented in Table 2, according to the window of diet exposure (antenatal, childhood diet, adulthood diet).

Maternal Dietary Patterns During Pregnancy

Up to 2009, only one study was published regarding the association between maternal dietary patterns during pregnancy and wheeze in offspring; it reported that adherence to the Mediterranean score during pregnancy was significantly and negatively associated with persistent wheeze, atopic wheeze, and atopy at age 6.5 years [27].

Since 2009, three studies have been published regarding the association between maternal dietary patterns during pregnancy and wheeze in offspring—one in the United States [23•], one in the United Kingdom [28], and the other in Japan [29].

In the US study (Project VIVA), including 1,376 mother–infant pairs, a comprehensive assessment of dietary patterns was conducted with both *a priori* (Mediterranean diet score, AHEI-P), and *a posteriori* patterns [23•]. After adjustments for confounders, none of these dietary patterns was associated with recurrent wheeze at age 3 years in children.

The United Kingdom study [28] involved a large number of mother–infant pairs ($n=12,008$), as well as a long follow-up of children (until age 7 years). Five dietary patterns were derived using a principal component analysis and labeled “health conscious,” “traditional,” “processed,” “vegetarian,” and “confectionery” patterns. After adjustment for potential confounders, no association was reported between these five dietary patterns during pregnancy and asthma and related outcomes at 7 years (early wheezing phenotype, wheeze at 3.5 and 7 years) in the offspring.

The more recent study was conducted in Japan among 763 mother–infant pairs [29]. Using principal component analysis, the authors derived three dietary patterns: “healthy,” “Western,” and “Japanese.” After adjustments for confounders, a negative and significant association between the Western pattern and the risk of wheeze (OR, 0.59 [95 % CI, 0.35–0.98]) was reported. These results highlighted the issue of the labeling of patterns because the so-called Western diet in Japan is not the same as the so-called Western diet in Europe or the United States. The Western

Table 2 Selected studies (since 2009) relating dietary patterns and timing (antenatal, childhood, adulthood) to asthma or wheeze

Study	Country, population, study design	Respiratory phenotype	Dietary patterns (a priori, a posteriori)	Results	Comments
Maternal dietary patterns during pregnancy					
Lange et al. [23•]	United States (Project Viva); 1,376 mother–infant pairs; longitudinal	Wheeze at 3 y	A) <i>A priori</i> dietary patterns: 1) Mediterranean diet score, 2) Alternate Healthy Eating Index modified for pregnancy B) <i>A posteriori</i> dietary patterns (PCA): 1) Prudent, 2) Western	No association between dietary patterns and recurrent wheeze in the offspring	–
Shaheen et al. [28]	UK (ALSPAC study); 12,008 mother–infant pairs; longitudinal	Early wheezing phenotype; wheezing at 3.5 y; wheezing, and physician-diagnosed asthma at 7 y	<i>A posteriori</i> dietary patterns (PCA): 1) Health conscious, 2) Traditional, 3) Processed, 4) Vegetarian, 5) Confectionery	No association between dietary patterns and asthma and related outcomes in the offspring	–
Miyake et al. [29]	Japan, 763 mother–infant pairs, longitudinal	Wheeze in the offspring aged 16–24 mo	<i>A posteriori</i> dietary patterns (PCA): 1) Healthy, 2) Western, 3) Japanese	Negative and significant association between the Western pattern and the risk of wheeze (OR, 0.59 [95 % CI, 0.35–0.98])	No association between these patterns and eczema
Dietary patterns during childhood					
Arvaniti et al. [34]	Greece; 700 children (10–12 years old); cross-sectional	Ever having had wheeze, ever having been diagnosed with asthma, asthma symptoms (ISAAC II criteria)	<i>A priori</i> score: KIDMED (Mediterranean diet score for children)	Greater adherence to the Mediterranean diet inversely associated with ever having had wheeze (8 % vs 29 %; $P=0.001$), ever having had diagnosed asthma (3 % vs 16 %; $P=0.002$), and with any asthma symptoms (5 % vs 34 %; $P<0.001$)	–
Nagel et al. [35]	20 countries (ISAAC); 50,004 children (8–12 years old); cross-sectional	Wheeze in the past 12 mo, asthma ever	<i>A priori</i> score: adapted Mediterranean diet score for children	Greater adherence to the Mediterranean diet inversely associated with wheeze (OR, 0.97 [95 % CI, 0.94–0.99]) and asthma (OR, 0.95 [95 % CI, 0.92–0.99])	–
Gonzalez Barcala et al. [36]	Spain; 14,700 children; cross-sectional	Prevalence and severity of asthma	<i>A priori</i> score: adapted Mediterranean diet score for children	Overall, no association between the Mediterranean diet score and asthma prevalence and severity; among girls 6–7 years old, greater adherence to the Mediterranean diet associated with a higher risk of severe asthma (OR, 2.26 [95 % CI, 1.21–4.22])	–
Dietary patterns during adulthood					
Bakolis et al. [42]	UK; 1,453 adults (16–50 years of age); case-control	Asthma, asthma severity	<i>A posteriori</i> dietary patterns (PCA): 1) Prudent, 2) Vegetable and fruit, 3) Western, 4) Vegetarian, 5) Traditional	Overall, borderline significant positive association between “vegetarian” dietary pattern and asthma (OR, 1.43 [95 % CI, 0.93–2.20]), and negative association between “traditional” pattern and asthma (OR, 0.68 [95 % CI, 0.45–1.03]); no associations with asthma severity	“Prudent” dietary pattern positively associated with chronic bronchitis

Table 2 (continued)

Study	Country, population, study design	Respiratory phenotype	Dietary patterns (<i>a priori</i> , <i>a posteriori</i>)	Results	Comments
Hooper et al. [43]	Three countries in the European Community Respiratory Health Survey-II (Germany, UK, Norway); 1,174 adults (29–55 years of age); cross-sectional	Current asthma, asthma symptoms, and bronchial responsiveness	<i>A posteriori</i> dietary patterns (PCA): 1) Meat and potato, 2) Fish, fruits, and vegetables	Overall, no association between respiratory phenotypes and dietary patterns; heterogeneity between countries for the asthma symptom score with the meat and potato pattern 1) Negative association in German center (OR, 0.87 [95 % CI, 0.69–1.09] and OR, 0.74 [95 % CI, 0.56–0.99], respectively, in Hamburg and Erfurt) 2) Positive association in UK and Norway center (OR, 1.42 [95 % CI, 1.07–1.88]; OR, 1.25 [95 % CI, 0.90–1.74]; and OR, 1.24 [95 % CI, 1.00–1.55], respectively in Ipswich, Norwich, and Bergen)	–
McKeever et al. [44•]	Netherlands (MORGEN-EPIC study); 12,648 adults; cross-sectional	Asthma ever, current wheeze (past 12 mo)	<i>A posteriori</i> patterns (PCA): 1) Cosmopolitan, 2) Traditional, 3) Refined food	Positive and significant association between the cosmopolitan diet pattern and prevalence of wheeze (OR, 1.3 [95 % CI, 1.0–1.5]) and asthma (OR, 1.4 [95 % CI, 1.0–2.0])	–
Varraso et al. [45•]	France (E3N study, French part of EPIC); 54,672 women; longitudinal	Ever having had adulthood asthma, current asthma, frequent asthma attacks, and adult onset of asthma	<i>A posteriori</i> dietary patterns (PCA): 1) Prudent, 2) Western, 3) Nuts and wine	No association between dietary patterns and asthma incidence, ever having had asthma, or current asthma; positive and significant association between the Western pattern and frequent asthma attacks; negative and significant association between the nuts and wine pattern and frequent asthma attacks (Fig. 1)	–

PCA principal component analysis

pattern in the Japanese study was characterized by high intake of vegetable oil, salt-containing seasonings, beef and pork, processed meat, eggs, chicken, and white vegetables and low intake of fruit, soft drinks, and confectioneries, and was significantly positively correlated with intake of α -linolenic acid, vitamin E, and β -carotene.

Overall, the evidence is weak, but these studies favor no association between dietary pattern during pregnancy and asthma/wheeze in the offspring.

Dietary Patterns During Childhood

Up to 2009, four cross-sectional studies were published regarding the association between childhood dietary patterns and asthma/wheeze, and overall, a positive association was reported between adherence to a Mediterranean diet and asthma [30–33].

Since 2009, only three studies have been published regarding the association between childhood dietary patterns and asthma/wheeze, one in Greece [34], one including 20 countries from the International Study on Allergies and Asthma in Childhood (ISAAC) [35], and the last one in Spain [36]. All had a cross-sectional design and used the *a priori* Mediterranean diet score adapted for children.

The Greek study [34] involved 700 children 10 to 12 years old; using the KIDMED score, the authors reported that greater adherence to the score was inversely associated with ever having had wheeze (8 % vs 29 %; $P=0.001$), ever having had diagnosed asthma (3 % vs 16 %; $P=0.002$), and with any asthma symptoms (5 % vs 34 %; $P<0.001$).

Nagel et al. [35] studied the association between the adapted Mediterranean diet score for children and current wheeze and ever having had asthma among 50,004 children 8 to 12 years old from 29 centers in 20 countries. They reported that greater adherence to the Mediterranean diet was inversely associated with wheeze in the past 12 months and ever having had asthma.

The Spanish study involved 14,700 children split into a first group aged 6 to 7 years and a second group aged 13 to 14 years [36]. Using an adapted Mediterranean diet score for children, the authors reported no association between the score and asthma prevalence and severity. In a subanalysis among girls aged 6 to 7 years, greater adherence to the score was associated with a higher risk of severe asthma (OR, 2.26 [95 % CI, 1.21–4.22]).

Overall, these studies are in favor of an association between dietary patterns during childhood and asthma and wheeze, even if they all are cross-sectional and prone to reverse causation. There is an urgent need for longitudinal studies to help us better understand the role of diet in the etiology of asthma.

Dietary Patterns During Adulthood

Up to 2009, five studies had been published [37–41]. The three longitudinal studies performed among large populations (>40,000 participants) reported no association between dietary patterns and adult-onset asthma [37–39]. Among the two cross-sectional studies, one reported a strong association between the Mediterranean diet score and asthma control among asthmatics [40], and the other one (conducted in Japan) reported a positive and significant association between wheeze and the fast food and quick sugar pattern [41].

Since 2009, four studies have been published: one case-control study [42], two cross-sectional studies [43, 44•], and one longitudinal study [45•].

The case-control study was performed among 1,453 participants aged 16 to 50 years and living in Greenwich in the United Kingdom [42]. Five dietary patterns were derived using a principal component analysis and labeled “prudent” pattern (high intake of whole-grain bread, yogurt, cheese, fish, salad, couscous, and vegetable dishes), “vegetable and fruit” pattern (high intake of vegetables and fruits), “Western” pattern (high intake of white bread, chips, potatoes, baked beans, processed meats, crisps, meat dishes, fried snacks, chocolate, ketchup, and soft drinks), “vegetarian” pattern (high intake of cream, macaroni and cheese, chick peas, hummus, lentils, vegetables, and nuts), and “traditional” pattern (high intake of vegetables, pork, beef, liver, and lamb, and a low intake of nan paratha). A borderline significant positive association was reported between the vegetarian dietary pattern and asthma (OR, 1.43 [95 % CI, 0.93–2.20]), and a negative association between traditional pattern and asthma (OR, 0.68 [95 % CI, 0.45–1.03]). These results became significant when the population was restricted to the non-supplement users. The labeling of the vegetarian pattern is quite misleading because it was mainly loaded by dairy products, white pasta, and legumes. No associations were observed with asthma severity.

The first cross-sectional study was performed in 1,174 adults aged 29 to 55 years from three countries (Germany, United Kingdom, Norway) involved in the European Community Respiratory Health Survey-II [43]. Using principal component analysis, two dietary patterns were derived and labeled the “meat and potato” pattern (high intake of sliced meat, beef, pork, bacon, sausage and fried eggs/scrambled eggs/omelettes, potatoes, and chips), and the “fish, fruits, and vegetables” pattern (fruits, vegetables, and fish). Overall, no association was reported between respiratory phenotypes (current asthma, asthma symptoms score) and dietary patterns. There was heterogeneity between centers in the association with symptom score: a negative association reported at the two German centers (OR, 0.87 [95 % CI, 0.69–1.09] and OR, 0.74 [95 % CI, 0.56–0.99], respectively, in Hamburg and Erfurt), and a positive association in the United Kingdom and Norway center

(OR, 1.42 [95 % CI, 1.07–1.88]; OR, 1.25 [95 % CI, 0.90–1.74]; and OR, 1.24 [95 % CI, 1.00–1.55], respectively, in Ipswich, Norwich, and Bergen). The authors concluded that heterogeneity in a multicenter observational study of diet could suggest alternative explanations for apparent effects of diet, such as uncontrolled confounding.

The second cross-sectional study was performed in The Netherlands among 12,648 adults aged 20 to 59 years and enrolled in the Monitoring Project on Risk Factors and Chronic Diseases in the Netherlands–European Prospective Investigation into Cancer and Nutrition [44•]. Using principal component analysis, three dietary patterns were derived and labeled: the “cosmopolitan” pattern (high intake of vegetables, fish, chicken, wine, and rice and low intake of high-fat dairy products, added fat, added sugar, and potatoes), the “traditional” pattern (high intake of red meat, processed meat, potatoes, boiled vegetables, added fat, coffee, and beer and low intake of soy products, low-fat dairy products, tea, breakfast cereal, brown rice, pizza, juice, and fruit), and the “refined food” pattern (high intake of mayonnaise, salty snacks, candy, high-sugar beverages, French fries, white bread, and pizza and lower intake of boiled vegetables, whole-grain bread, fruit, and cheese). After adjustment for confounders, a high intake of the cosmopolitan diet pattern was associated with a small increased prevalence of wheeze (OR, 1.3 [95 % CI, 1.0–1.5]) and asthma (OR, 1.4 [95 % CI, 1.0–2.0]).

The only longitudinal study was performed among 54,672 women aged 40 to 65 years and enrolled in the E3N study in 1990 [45•]. Using principal component analysis,

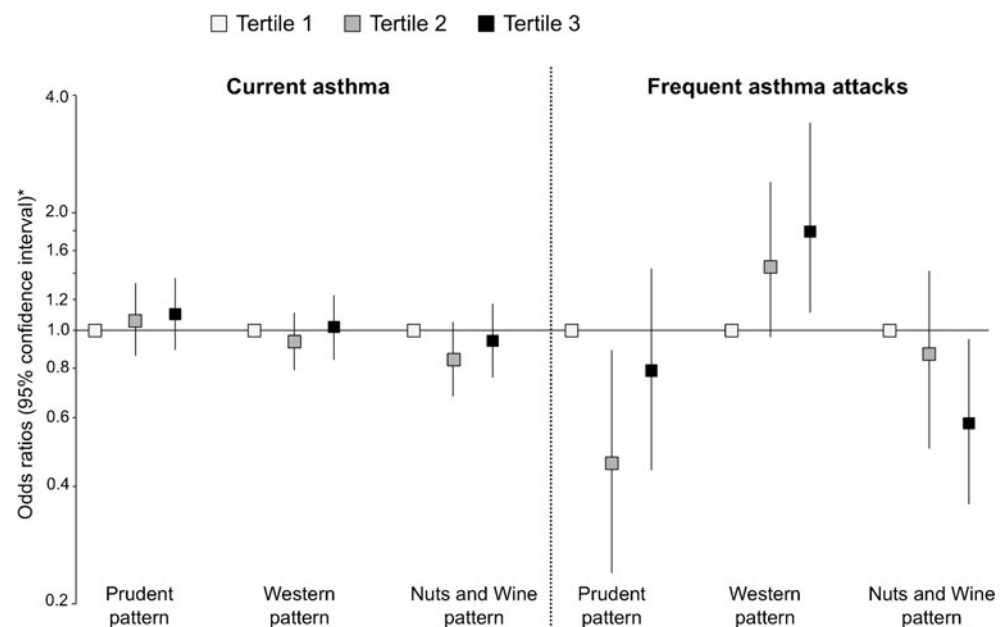
three dietary patterns were derived and labeled: the “prudent” pattern (high intake of fruits and vegetables), the “Western” pattern (high intake of pizza/salty pies, dessert, cured meats, and pasta), and the “nuts and wine” pattern (high intake of nuts and seeds, salty biscuits, olives, wine, and fortified wine). After adjustment for confounders, we reported no association between dietary patterns and asthma incidence, ever having asthma, or current asthma both among all women and among women without multivitamin supplement use (Fig. 1). Among women without multivitamin supplement use, a positive and significant association between the Western pattern and frequent asthma attacks, and a negative and significant association between the nuts and wine pattern and frequent asthma attacks were reported (Fig. 1).

Overall, the results are conflicting. In cross-sectional studies, dietary patterns are associated with asthma; however, these findings were not confirmed in longitudinal surveys. Regarding asthma severity and control, few studies were performed, but dietary patterns are reported to be associated among asthmatics with frequent asthma attacks and with asthma control. Further studies are needed to better understand how diet might modulate asthma severity and/or control in adults.

Conclusions

Taken together, data are still conflicting regarding the association between diet and asthma. Some associations are well-documented, such as the association between asthma and the intake of fruit and vegetables in children and adults,

Fig. 1 Association between dietary patterns in adulthood (prudent, Western, nuts and wine) with current asthma ($n=33,263$) and frequent asthma attacks ($n=566$), among women from the E3N study without multivitamin supplement use. The prudent pattern is characterized by a high intake of fruits and vegetables, the Western by a high intake of pizza/salty pies, desserts, cured meats, and pasta, and the nuts and wine by a high intake of nuts and seeds, salty biscuits, olives, wine, and fortified wine. BMI body mass index. (Adapted from Varraso et al. [47])



Odds ratios are adjusted for age, caloric intake, BMI, tobacco consumption, physical activity, education and menopausal status.

or the adherence to the Mediterranean diet in children. However, for most dietary exposures, including antioxidant vitamins, n-3 PUFAs, vitamin D, and dietary patterns, the window of exposures (antenatal, childhood, adulthood), the evaluation of exposure, and the interpretability of the results related to the study design are far from clear. All these findings underscore the importance of conducting prospective studies and clinical trials to help us better understand the role of diet in the etiology of wheeze and asthma.

Besides nutrition per se, the interrelationships among nutritional factors (diet, obesity, physical activity) provide important challenges for epidemiologic researchers. Diet is also an essential aspect of lifestyle, with specificities between countries and social groups due to cultural, social, and environmental factors. Foods that are commonly and easily grown in a specific region frequently become a part of the local cuisine. The social context in which a child's eating patterns develop is important because the local environment serves as a model for the developing child [46]. Accordingly, there is a need for further research to disentangle the independent effect of each nutritional and lifestyle factor on asthma risk by using, for example, causal models. This analytic approach allows testing of different models of causality in the epidemiology of disease arising out of environmental factors, and analyzes the interplay among these factors. Such an approach may help us find a stronger scientific basis to support nutritional recommendations that lower the risk of asthma.

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