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REVIEW ARTICLE

Asthma and dietary intake: an overview of systematic reviews

V. Garcia-Larsen[1], S. R. Del Giacco[2], A. Moreira[3,4], M. Bonini[5], D. Charles[1], T. Reeves[6], K.-H. Carlsen[7], T. Haahtela[8], S. Bonini[9], J. Fonseca[4], I. Agache[10], N. G. Papadopoulos[11] & L. Delgado[3,4]

[1]Respiratory Epidemiology, Occupational Medicine, and Public Health Group, National Heart and Lung Institute, Imperial College London; [2]Department of Medical Sciences 'M Aresu', University of Cagliari, Cagliari, Italy; [3]Faculty of Medicine, University of Porto and Hospital São João, ; [4]CINTESIS – Center for Health Technology and Services Research, Faculty of Medicine, University of Porto, Porto, Portugal; [5]Department of Internal Medicine, Lung Function Unit, Sapienza University of Rome; [6]Central Library, Imperial College London, London, UK; [7]Department of Medicine and Allergology, University of Oslo, Oslo, Norway; [8]Skin and Allergy Hospital, Helsinki University Central Hospital, Helsinki, Finland; [9] Second University of Naples and IFT-CNR, Rome, Italy; [10]Transylvania University Brasov, Brasov, Romania; [11]Centre for Paediatrics and Child Health, Institute of Human Development, The University of Manchester, Manchester, UK

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Correspondence
Vanessa Garcia-Larsen, Emmanuel Kaye Building, Manresa Road, London SW3 6LR, UK.
Tel.: 004402075945497
E-mail: v.garcialarsen@imperial.ac.uk

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Abstract

Epidemiological research on the relationship between diet and asthma has increased in the last decade. Several components found in foods have been proposed to have a series of antioxidant, anti-allergic and anti-inflammatory properties, which can have a protective effect against asthma risk. Several literature reviews and critical appraisals have been published to summarize the existing evidence in this field. In the context of this EAACI Lifestyle and asthma Task Force, we summarize the evidence from existing systematic reviews on dietary intake and asthma, using the PRISMA guidelines. We therefore report the quality of eligible systematic reviews and summarize the results of those with an AMSTAR score ≥32. The GRADE approach is used to assess the overall quality of the existing evidence. This overview is centred on systematic reviews of nutritional components provided in the diet only, as a way to establish what type of advice can be given in clinical practice and to the general population on dietary habits and asthma.

Diet constitutes an important source of nutrients and non-nutrient components with multiple properties that might modulate the risk of asthma and other chronic respiratory diseases in the population (1, 2). The characteristic features of oxidative stress and inflammation that are central to the clinical manifestation of asthma make diet a potentially key factor in the modulation of this disease (2). Such association has been increasingly studied in observational and intervention studies. To date, epidemiological evidence from observational studies is suggestive of a possible protective effect of intake of fresh foods (mainly vegetables and fruits) (3). Well-designed randomized controlled trails (RCTs) have been carried out to test the effect of antioxidant supplements on asthma risk (4, 5) and asthma severity (6) but results have so far been disappointing. More recently, evidence from dietary interventions using increased net intake of dietary sources of antioxidants in asthmatic adults shows some moderate but promising results in improved lung function and markers of inflammation in asthmatic adults (7).

Understanding the evidence on the possible effect of food intake on asthma can contribute to introduce clinical guidelines and public health recommendations to the population. The Global Initiative for Asthma Guidelines (GINA) includes amongst its recommendations, the practice of a healthy diet for the primary prevention of asthma (8). However, there are still important gaps in the interpretation of the type of foods or diets that the population should incorporate to improve their health. This is partly due to the fact that the complexity of the association between diet and asthma lies with the definitions and categorizations of both terms. Epidemiological studies differ greatly in the measures of dietary exposures and in the use of agreeable definitions of asthma. To facilitate an adequate interpretation of the existing evidence, high-quality systematic reviews are needed. As part of the work of the EAACI Evidence-Based Clinical Practice Guideline Task Force on Lifestyle Interventions in allergy and asthma, we carried out an overview of existing systematic reviews on food intake and asthma.

Methods

Search strategy and study selection

Systematic reviews published until December 2013, with no specific start date, were considered for inclusion. We searched MEDLINE and EMBASE (via OVID), and the Cochrane Database and DARE (via the Cochrane Library). The strategy for identifying existing systematic reviews was based on published methods showing this to be a sensitive and specific strategy for identifying systematic reviews (9). The search strategies used are included as Appendix S1 to this manuscript. The following relevant terms for outcomes were included for our search in MEDLINE: asthma ab, ti. Asthma/wheeze ab, ti; wheezing ab, ti; bronchial hyper-responsiveness ab, ti; bronchial hyper-reactivity ab, ti; bronchial hyper-reactivity/; 1 or 2 or 3 or 4 or 5 or 6 or 7. Existing systematic reviews were included in the current overview if they investigated the association between any foods or diets and risk of asthma. Accepted definitions of asthma were 'self-reported asthma', 'Dr-diagnosed asthma' and 'wheeze', as well as objective measures of asthma (bronchial hyper-responsiveness). Reviews on artificial supplementation (e.g. supplementation) were excluded from this overview.

Quality assessment

Eligible systematic reviews were appraised using the revised AMSTAR criteria. AMSTAR is an 12-item tool to assess the methodological quality of systematic reviews that has been internally and externally validated and has been found to have good reliability (10). A score ≥32 was used as cut-off to consider them of high quality and to be included in the analyses. As far as possible, these data were presented using Cochrane Summary of Findings Tables, generated using Gra-

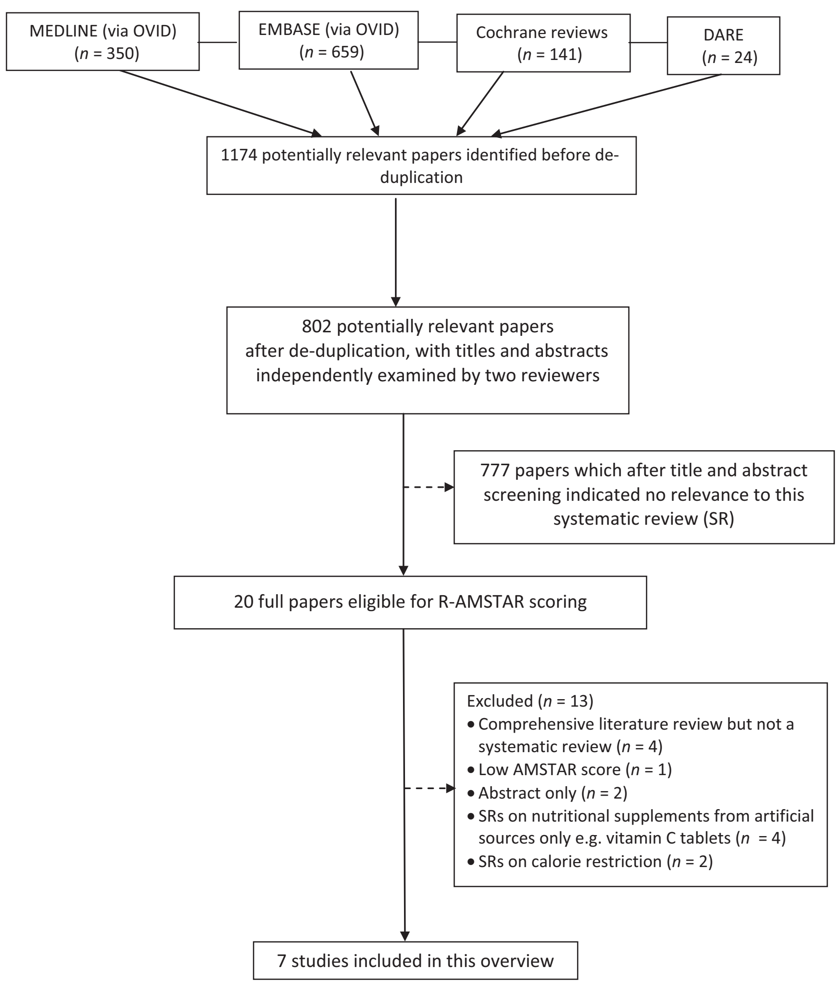

Figure 1 PRISMA flow diagram overview of existing systematic reviews (SRs) on dietary exposures and asthma in the life course.

dePro. Characteristics of included studies were summarized in a Table for all included reviews. Data were independently extracted by two authors (VGL, SDG). Any discrepancies were discussed with a third member of the research team.

Results

After identifying 1174 papers potentially relevant for the overview, 802 titles and abstracts were examined for potential eligibility, of which 20 were considered relevant and fully examined for inclusion (Fig. 1). Of these, there were seven systematic reviews that met the AMSTAR score for high quality (≥32) (3, 11–16), whilst one study was excluded for scoring below this mark (17). Four articles were literature reviews or critical appraisals (18–21), and six were systematic reviews on specific nutrients given as artificial supplements only (22–25) or on calorie restriction (26, 27). There were two abstracts excluded, one with no further information (28) and a second abstract which was followed by a noneligible publication (29) (Table 1).

The characteristics of the seven eligible systematic reviews are summarized in Table 2. Dietary intake of antioxidant vitamins, minerals or single foods was examined in two systematic reviews that included 40 (11) and 62 studies (3). Both systematic reviews only included observational study designs. Two systematic reviews examined the evidence on risk of asthma and exposure to fish intake (15, 16). The systematic review by Yang et al. (15) identified 11 eligible studies, whilst Thien et al. (16) included nine randomized controlled trials (RCTs). In the latter, although studies were identified on actual fish intake as exposure, there were no studies eligible for effect comparison and only trials with artificial fish oil supplementation were included in their results. One systematic review analysed the evidence from eight observational studies on various measures of Mediterranean diet adherence in and various outcomes of asthma (wheeze) and severity in children (13). Two systematic reviews investigated the effect of diets with high, low and normal levels of salt on adult asthma. The systematic review by Ram and Ardern (12) included six RCTs and that by Pogson and McKeever (14) included three RCTs.

The overall effects reported by the high-quality systematic reviews included in this overview are summarized in Table 3. Evidence on the following dietary exposures was comparable and therefore analysed: vitamins A, C, D and E, dietary intake of fruits and vegetables, Mediterranean diet, intake of fish or omega 3 fatty acids and salt intake. With regard to antioxidant vitamins, Allen et al. (11) reported an overall increased risk of asthma with decreasing intakes of vitamin C in ten observational studies (OR 1.12; 95% confidence interval [CI] 1.04–1.21) and on wheeze (OR 1.10; 95% CI 1.00–1.20), with no evidence of heterogeneity across studies (I^2 = 0.0%). There was no evidence of an effect of maternal vitamin C intake and infant wheeze (OR 1.30; 95% CI 0.47–3.62) in the two included studies (cohorts), and their heterogeneity was very high (I^2 = 88.6%) (11).

Maternal intake of vitamin D was negatively associated with risk of recurrent wheeze or wheeze in the last 12 months in children (OR 0.56; 95% CI 0.42–0.73) in four meta-analysed cohort studies. There was small evidence of heterogeneity in these studies (I^2 = 15.8%) (3). No evidence of an association was observed in two meta-analysed cohort studies on maternal exposure to vitamin D and risk of childhood asthma, with their meta-analysis showing high level of heterogeneity (I^2 = 72.8%) (3). Four meta-analysed cross-sectional studies showed that dietary intake of fruit (but not vegetable) was negatively related to wheeze in children aged 10–14 (OR 0.75; 95% CI 0.61–0.94), with high evidence of heterogeneity (I^2 = 0.66%) (3). Adherence to a Mediterranean diet was related to a lower risk of current wheeze in children in a meta-analysis of nine cross-sectional studies (OR 0.85; 95% CI 0.75–0.98), and this negative association was also confirmed when only studies from Mediterranean cities were combined

Table 1 Quality assessment of existing relevant systematic reviews on asthma or wheeze and food intake using R-AMSTAR scoring

First author [reference]	Agreed R-AMSTAR score	Decision
Allen (11)	32	Included
Ram(12)	37	Included
Cheng (26)		Excluded – Calorie restriction only
Gao (17)	27	Excluded
Galli (18)		Excluded – Literature review
Garcia-Marcos (13)	33	Included
Horvath (28)		Excluded – Abstract only with no further publication
Kaur (22)		Excluded – Vitamin C as artificial supplement only
Klemens (23)		Excluded – PUFA as artificial supplement only
Klemens (29)		Excluded – Abstract only (full SR above)
Kremmyda (19)		Excluded – Literature review
Milan Stephen (24)		Excluded – Vitamin C as artificial supplement only
Moore (20)		Excluded – Literature review
Mulholland (27)		Excluded – Calorie restriction only
Nurmatov (3)	35	Included
Pogson (14)	37	Included
Reisman (25)		Excluded – Ω-3 fatty acids as artificial supplements only
Saadeh (21)		Excluded – Review/appraisal article
Yang (15)	34	Included
Thien Francis (16)	37	Included – Ω-3 fatty acids as artificial supplements but it contains a section on fish intake

*An agreed score of ≥32 achieved by two reviewers was considered acceptable for inclusion in this overview.

Table 2 Summary characteristics of eligible existing systematic reviews on dietary exposures and outcomes relevant to this systematic review

Author [reference]	Databases searched (end date)	No. studies No. participants	Study designs included	Population	Intervention/Exposure (s)relevant to this SR	Outcomes relevant to this SR	Subgroup analyses relevant to this SR
Allen (11)	MEDLINE, EMBASE, CINAHL, CAB abstracts and AMED (November 2007)	40 studies included in SR Not reported	Cohort Case–control Cross-sectional	Children Adults	Dietary intake of vitamins A, C, and E	Asthma Wheeze BHR	Sub-analyses by age group, and by dietary antioxidant vitamin
Ram (12)	Cochrane Airways Group Register* (February 2004)	6 studies included No. patients in each trial ranged between 17 and 36	Only RCTs	Adults or children	Comparison between normal salt diet *vs* high or low	(All subjects are asthmatics) Lung function outcomes BHR	Dietary salt reduction (low salt diet *vs* untreated group or normal salt diet Salt supplemented diet or high salt diet *vs* normal salt diet Dietary salt reduction *vs* salt supplemented diet or high salt diet
Garcia-Marcos (13)	MEDLINE/PubMed, EMBASE, Scopus, ISI Web of Knowledge (May 2012)	8 studies included 39 804 participants	All cross-sectional	Children	Valid measures of Mediterranean diet score/adherence	Current wheeze Severe wheeze Asthma ever	Adherence to Mediterranean diet assessed separately by outcome Subgroup analyses by Mediterranean or non-Mediterranean areas
Nurmatov (3)	MEDLINE, EMBASE, Global Health, CAB, AMED, Web of Science, BIOSIS, CINAHL, LILACS, Cochrane Library, TRIP (May 2009)	62 studies included Total No. participants not reported	Cohort Case–control Cross-sectional	Children (including exposure during pregnancy)	Dietary intake of vitamins and minerals Dietary intake of foods and food groups	Asthma/wheeze outcomes Increased/decreased severity (secondary outcomes)	Meta-analyses (where comparable data available) on individual nutrients/foods and each outcome
Pogson (14)	Cochrane Airways Group Specialized Register of Trials* (November 2010)	9 studies included (5 in people with asthma [A]; 4 in people with 'exercise-induced asthma' [EIA]) [A] 318 participants [EIA] 63 participants	Only RCTs	Adults or children	Increased or decreased dietary intake of sodium	BHR in subjects with asthma (primary outcome) Asthma QoL Lung function measurements (FEV_1; FEV_1/FVC), Peak expiratory flow rate (PEFR)	No sub-analyses
Yang (15)	PubMed (December 2012)	15 studies included in the SR; 8 studies included in meta-analysis. For participants see footnote‡	RCTs and prospective cohort studies	Adults or children	Dietary intake of fish or fish oil consumption	Incidence of asthma	No sub-analyses
Thien (16)	Central, Embase, Medline, Cinahl (2001)	9 RCTs included in SR; 1 study eligible for this overview	RCTs	adults or children	Dietary fish oil supplementation	asthma outcomes, lung function measurements (FEV, PEFR, BHR)	

*The Cochrane Airways Group Specialized Register Trials includes the following databases: CENTRAL, MEDLINE, EMBASE, CINAHL, AMED and PsycINFO.
†The SR by Thien et al. included one study with fish as actual food, therefore included in our overview.
‡In the study by Yang et al., the total number of participants was described as follows: Fish intake and risk of asthma: 12 481 children and 996 cases identified during 1–6 years of follow-up; Levels of n−3 fatty acids in breast milk and incident asthma: 276 children; Risk of asthma in offspring according to maternal intake of fish: 786 cases/2832 individuals.

Table 3 Evidence from existing systematic reviews on the effect of dietary exposures on asthma or wheeze*

Author [reference]	Outcome measure	Exposure/type of studies Combined (if info available)	No. participants (studies) contributing data	Outcome (95% CI)	Heterogeneity
Vitamin A or derivatives					
Allen (11)	Asthma	Dietary intake of vitamin A (μg/day) Case–control studies	(3)	MD −181.84 (−288.4 to −75.3)	I^2 = 0.0%
Nurmatov (3)	Wheezing in the 2nd year of life	Maternal intake of β-carotene Cohort studies	2664 (2)	OR 1.05 (0.76–1.44)	I^2 = 0.0%
Vitamin C					
Allen (11)	Asthma	Overall effect of vitamin C intake (mg/day) (lowest *vs* highest intakes)	(10)	**OR 1.12 (1.04–1.21)**	I^2 = 0.0%
		Cohort studies	(1)	OR 0.90 (0.57–1.44)	–
		Case–control studies	(3)	OR 1.13 (1.04–1.23)	I^2 = 0.0%
		Cross-sectional	(6)	OR 1.11 (0.90–1.37)	I^2 = 14.5%
	Wheeze	Overall effect of vitamin C intake (mg/day) (lowest *vs* highest intakes)	(7)	**OR 1.10 (1.00–1.20)**	I^2 = 0.0%
		Case–control study	(1)	OR 1.45 (0.71–2.96)	–
		Cross-sectional studies	(6)	OR 1.09 (1.00–1.19)	I^2 = 0.0%
Nurmatov (3)	Wheezing in the 2nd year of life	Maternal intake of vitamin C (highest *vs* lowest intakes) Cohort studies	2664 (2)	OR 1.30 (0.47–3.62)	I^2 = 88.6%
Vitamin E					
Allen (11)	Dr-diagnosed asthma	Dietary intake of vitamin E (mg/day)	(4)	MD −1.91 (−2.51 to −1.31)	I^2 = 0.0%
	Self-reported asthma	Dietary intake of vitamin E (mg/day)	(1)	MD −0.20 (−0.72 to 0.32)	–
Nurmatov (3)	Wheezing in the 2nd year of life	Maternal intake of vitamin E	3427 (3)	**OR 0.68 (0.52–0.88)**	I^2 = 0.0%
Vitamin D (cohort studies)					
Nurmatov (3)	Recurrent wheeze or wheeze in last year in children	Maternal intake of vitamin D	4838 (4)	OR 0.56 (0.42–0.73)	I^2 = 15.8%
	Asthma in children	Maternal intake of vitamin D	2881 (2)	OR 0.76 (0.39–1.48)	I^2 = 72.8%
Dietary intake of fruits (all studies are cross-sectional)					
Nurmatov (3)	Wheeze in children aged 10–14 years	Fruit intake (highest *vs* lowest level of intake compared)	19 949 (4)	**OR 0.75 (0.61–0.94)**	I^2 = 66.0%
Dietary intake of vegetables (all studies are cross-sectional)					
Nurmatov (3)	Wheeze in children aged 10–14 years	Vegetable intake (highest *vs* lowest level of intake compared)	16 120 (3)	OR 0.84 (0.64–1.10)	I^2 = 71.2%
Adherence to Mediterranean Diet (measured as a score) (all studies are cross-sectional)					

Table 3 (continued)

Author [reference]	Outcome measure	Exposure/type of studies Combined (if info available)	No. participants (studies) contributing data	Outcome (95% CI)	Heterogeneity
Garcia-Marcos (13)	Current wheeze in children	Non-Mediterranean cities	(3)	OR 0.91 (0.78–1.05)	I^2 = 26.5%
		Mediterranean cities	(6)	**OR 0.79 (0.66–0.94)**	I^2 = 43.6%
		All cities, all studies	(9)	**OR 0.85 (0.75–0.98)**	I^2 = 35.4%
	Current severe wheeze in children	Non-Mediterranean cities	(2)	OR 0.99 (0.79–1.25)	I^2 = 0.0%
		Mediterranean cities	(4)	OR 0.66 (−0.48 to 0.90)	I^2 = 42.9%
		All cities, all studies	(6)	OR 0.82 (0.55–1.22)	I^2 = 27.2%
	Asthma ever	Non-Mediterranean cities	(3)	OR 0.88 (0.75–0.98)	I^2 = 27.7%
		Mediterranean cities	(6)	OR 0.86 (0.74–1.01)	I^2 = 14.7%
		All cities, all studies	(8)	OR 0.88 (0.78–0.95)	I^2 = 19.4%
Dietary intake of fish or sources of ω-3 fatty acids (all cohort studies)					
Yang (15)	Dr-diagnosed asthma	Newborn's fish exposure	(3)	**OR 0.75 (0.61–0.94)**	I^2 = 11.5%
	Incidence of asthma	Fish intake in adults	(2)	OR 0.90 (0.69–1.18)	I^2 = 0.0%
	Incidence of asthma	Intake of ω-3 fatty acids in adults	(3)	OR 0.70 (0.46–1.05)	I^2 = 78.5%
Dietary intake of salt (sodium) (all RCTs in adults)					
Ardern (12)	PD_{20} (log µg)	Low salt *vs* normal salt diet	26 (1)	MD −0.30 (−1.12 to 0.52)	–
	FEV_1 (L)	Low salt *vs* normal salt diet	118 (4)	MD 0.09 (−0.19 to 0.38)	I^2 = 0.0%
	FVC (L)	Low salt *vs* normal salt diet	46 (2)	MD 0.11 (−0.45 to 0.67)	I^2 = 0.0%
	FEV_1/FVC	Low salt *vs* normal salt diet	74 (3)	MD −0.32 (−3.68 to 3.05)	I^2 = 0.0%
	PD_{20} (log µg)	High salt *vs* normal salt diet	26 (1)	MD 0.00 (−0.86 to 0.86)	N/A
	FEV_1 (L)	High salt *vs* normal salt diet	118 (4)	MD −0.09 (−0.38 to 0.20)	I^2 = 0.0%
	FVC (L)	High salt *vs* normal salt diet	46 (2)	MD −0.06 (−0.65 to 0.52)	I^2 = 0.0%
	FEV_1/FVC	High salt *vs* normal salt diet	74 (3)	MD 0.07 (−3.69 to 3.84)	I^2 = 0.0%
	PD_{20} (log µg)	Low salt *vs* high salt diet	26 (1)	MD 0–0.30 (−1.02 to 0.42)	N/A
	FEV_1 (L)	Low salt *vs* high salt diet	118 (4)	MD 0.18 (−0.11 to 0.48)	I^2 = 0.0%
	FVC (L)	Low salt *vs* high salt diet	46 (2)	MD 0.18 (−0.41 to 0.76)	I^2 = 0.0%
	FEV_1/FVC	Low salt *vs* high salt diet	74 (3)	MD −0.50 (−4.07 to 3.06)	I^2 = 0.0%
Pogson (14)	Asthma (BHR)	The authors reported that from the three eligible studies, data were not comparable due to the different substances used for provocation and differences in the presentation of data			

MD, mean difference; OR, odds ratio.
*Bold values indicate statistical significance (*P*-value<0.05)

Table 4 Evidence from existing systematic reviews on the effect of dietary intake of vitamin D for the prevention of asthma in children

Summary of Findings

Patient or population: Children
Settings: Population-based birth cohort studies in the USA, UK, Finland and Japan
Intervention/exposure: Dietary intake of vitamin D

	Illustrative comparative risks (95% CI)				
Outcomes	Assumed risk Control	Corresponding risk Vitamin D	Relative effect (95% CI)	No of Participants (studies)	Quality of the evidence (GRADE)
Wheeze in the last 12 months	Low-risk population		OR 0.56 (0.42–0.73)	4834 (4 studies)	⊕ ⊕⊖⊖ Moderate*,†,‡
	18 per 1000	56 per 1000 (42–73)			
	Medium-risk population				
	36 per 1000	136 per 1000 (84–146)			
	High-risk population				
	72 per 1000	204 per 1000 (168–296)			

The assumed risks are for populations at low, medium and high risk of developing wheeze. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the general population and the odds of having asthma or wheeze (and its 95% CI) given the specific dietary exposure.
CI, confidence interval; OR, odds ratio.
GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.
*The exposure to vitamin D was obtained from self-reported intake of foods from a dietary questionnaire. Due to the nature of vitamin D synthesis, plasma levels of vitamin D are a better predictor of Vitamin D status than data from FFQ.
†There was a low level of heterogeneity between studies (I^2 15.8%), and they were all of prospective cohort design.
‡The confidence intervals for the pooled effect were relatively narrow.

(n = 6; OR 0.79; CI 0.66–0.94). In both meta-analyses, there was moderate evidence of heterogeneity across studies (I^2 = 35.4% and I^2 = 43.6%, respectively). With regard to salt intake, there was no evidence of an effect of variable intakes of salt on lung function measures in asthmatic adults in the systematic review by Ram and Ardern (12).

Tables 4 and 5 show the quality of the studies for which combined evidence assessment could be drawn. Studies on vitamin D were considered of moderate quality, mainly supported by cohort designs used. The evidence on fruit intake was mostly obtained from cross-sectional studies and with relatively small samples therefore they had a low quality.

Discussion

In this overview of systematic reviews on dietary intake and asthma, we found seven systematic reviews that met the AMSTAR score for high quality. The results show evidence of a negative association between asthma or wheeze and dietary intake of vitamins C, E and D, as well as intake of fruits and adherence to a Mediterranean diet. Objective measures of asthma were unrelated to variable levels of intake of salt in RCTs. With the exception of the evidence for vitamin D, the associations observed between asthma and dietary intake of foods and antioxidant nutrients come mostly from cross-sectional studies.

There are several strengths of this overview. First, it employed a comprehensive search strategy, developed and piloted to capture all available systematic reviews that met the eligibility criteria of this Task Force's review. We also used AMSTAR as a validated instrument to assess in detail the methodological quality of included reviews. In spite of the abundant-scientific literature on asthma and diet, few systematic reviews meet the recommended cut-off score for high-quality reviews. These are needed to produce adequate guidelines for health professionals, patients and patient-affiliated associations.

Given the diversity in the way diet and asthma outcomes are measured in epidemiological studies, making results comparable remains a major challenge. We focused our overview

Table 5 Evidence from existing systematic reviews on the effect of dietary intake of fruits for the prevention of asthma in children

Summary of Findings

Patient or population: Children
Settings: Cross-sectional studies from the general population
Intervention/exposure: Dietary intake of fruit

	Illustrative comparative risks (95% CI)				
Outcomes	Assumed risk Control	Corresponding risk Fruit intake	Relative effect (95% CI)	No of Participants (studies)	Quality of the evidence (GRADE)
Wheeze in the last 12 months	Low-risk population		OR 0.75 (0.61–0.94)	19 949 (4 studies)	⊕ ⊖⊖⊖ Very low*,†,‡
	18 per 1000	75 per 1000 (61–94)			
	Medium-risk population				
	36 per 1000	150 per 1000 (122–188)			
	High-risk population				
	72 per 1000	300 per 1000 (244–376)			

The assumed risks are for populations at low, medium and high risk of developing wheeze. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the general population and the odds of having asthma or wheeze (and its 95% CI) given the specific dietary exposure.
CI, confidence interval; OR, odds ratio.
GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.
*All four studies are of cross-sectional design.
†High level of heterogeneity across pooled studies (I^2 66.0%).
‡The confidence intervals for the pooled effect was relatively narrow.

in accepted definitions of 'asthma' commonly used in epidemiological studies as a way to minimize the noise caused by the use of very different terms. Both 'self-reported asthma' and 'wheeze' have been considered to be reliable estimates of the disease, particularly in epidemiological studies in children. Often, consistency in the way the questions are asked in questionnaires helps to strengthen the identification of individuals who have asthma. The reporting of wheeze in population-based studies is the commonest approach used by epidemiologists to ascertain prevalence of asthma, particularly in children. In spite of the variations that the term might have across countries, the standardized used of wheeze-related questions is helpful. Recent advances to examine the usefulness of the use of wheeze as a proxy for asthma diagnosis in epidemiological studies have shown that recurrent (unremitting) wheeze is specific of childhood asthma and that it correlates highly with its clinically defined phenotype (30). Similarly, the use of parental reported Doctor-diagnosed asthma has been shown to be specific of the disease in epidemiological studies (31).

Most of the evidence of a protective effect of dietary antioxidants and asthma was found in children. A reduced risk of childhood wheeze with higher intakes vitamin D, fruits and adherence to Mediterranean diet was found in two systematic reviews (3, 13). These findings are mirrored in a recent cohort study on 1924 children, which showed that intake of vitamins D and E were negatively associated with asthma at age 10 (32). These results further support to the notion that actual intake of sources of antioxidants might have a beneficial effect against asthma. So far, the evidence from RCTs on dietary antioxidants (single or combined) has provided no justification to use nutritional supplements in the prevention or improvement of asthma management in adults and children (4–6).

Evidence from food interventions in asthmatic subjects is still very scant to understand the possible effect of specific foods on respiratory health, but several emerging studies suggest that RCTs with foods are possible. In adults, a food intervention with increased intake of daily portions of fruits and vegetables was associated with a reduction in markers of inflammation in asthmatic adults, but not with clinical outcomes of the disease (7). In pregnant women, an intervention is currently underway to test whether a net increase of dietary antioxidants can reduce the risk of asthma in the offspring (33). Garcia-Larsen et. al. recently demonstrated the feasibility of doing a fresh fruit intervention to test changes in asthma-related symptoms in a pilot study of asthmatic children aged 6–10 (34).

We identified two other systematic reviews published after our search strategy was carried out. Brigham et al. (35) examined the evidence on the association between adult asthma and 'Western' dietary patterns in ten observational studies. The authors reported no relation between risk of incidence or prevalence of asthma and having a 'Western' dietary pattern in combined analyses that included 70 000 individuals. There was marginal evidence of a positive association between symptoms of asthma severity and intake of a 'Western' dietary pattern. Netting et al. (36) recently showed in their systematic review on maternal dietary exposure and asthma that there was a lower risk of asthma in the offspring of mothers who had a Mediterranean dietary pattern, or consumed diets rich in fruits and vegetables, fish and vitamin D-containing foods.

Our overview of systematic reviews was limited to dietary exposures included in the actual diet rather than in the use of nutrient supplements. This focus was intended to provide evidence of the effect of food intake, as a tangible measure to give public health advice. We restricted the scope of this overview to asthma, wheeze or lung function measures in asthmatic subjects; therefore, interpretation of findings should be kept within the limits of these outcomes.

Overall, this overview of systematic reviews shows evidence of a beneficial effect of fresh fruits, and antioxidant vitamins on asthma. The time of exposure would seem to be important, as protective effects appear more clearly in early life and childhood. This evidence supports recommendations in clinical practice to increase the net intake of fruits and vegetables as a way of reducing the risk of asthma, particularly in children. The current evidence comes mostly from observational studies and highlights the need for well-designed RCTs to investigate whether such an effect has clinical benefits. The high prevalent rates of asthma in the general population, particularly in children, justify the implementation of such studies.

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Conflicts of interest

All authors declare no conflict of interest.

Contributions

VGL carried out the search strategy and data extraction and wrote the first draft of the manuscript. The scope of the manuscript with regard to dietary exposures and respiratory outcomes was discussed *a priori* and approved by all the co-authors. VGL and SDG independently selected eligible titles and extracted the data. Discrepancies and consistency were discussed with AM who also advised on the grading of the evidence. TR advised on the technical aspects of the search strategy and helped to pilot the searches and produce the final search strategy. MB, DC, K-HC, TH, SB, IA, JF, NP and LD contributed equally to the writing of the manuscript and to the interpretation of the results. All co-authors discussed and agreed on each of the stages of the data extraction and synthesis of the data. All co-authors approved the final version of the manuscript.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Search strategy for overview of existing systematic reviews.

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