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SYSTEMATIC REVIEW

Is the consumption of fast foods associated with asthma or other allergic diseases?

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ABSTRACT

The associations between the consumption of fast foods and asthma or allergic diseases have not been clarified. The aim of this study was to determine whether fast foods consumption is associated with asthma or allergic diseases. Databases were searched up to February 2018. Studies investigating the associations between fast foods consumption and asthma or allergic diseases were considered eligible. Included studies were assessed for quality using standardized critical appraisal checklists. The quality scores were 5.33 ± 1.16 in case–control studies and 5.69 ± 1.55 in cross-sectional studies. Adjusted odds ratios (aOR) with 95% confidence interval (CI) were pooled. Sixteen studies (13 cross-sectional and 3 case–control studies) were included. The consumption of fast foods was significantly related to current asthma (aOR: 1.58; 95% CI: 1.17–2.13 for case–control study and aOR: 1.58; 95% CI: 1.10–2.26 for cross-sectional studies), severe asthma (aOR: 1.34; 95% CI: 1.23–1.46), asthma ever (aOR: 1.36; 95% CI: 1.06–1.75), current wheeze (aOR: 1.21; 95% CI: 1.16–1.27), wheeze ever (aOR: 1.65; 95% CI: 1.07–2.52), physician-diagnosed allergic rhinitis (odds ratio: 1.43; 95% CI: 1.05–1.95), severe eczema (aOR: 1.51; 95% CI: 1.16–1.96) and severe rhino-conjunctivitis (aOR: 1.54; 95% CI: 1.18–2.00). The consumption of hamburgers was associated with current asthma (aOR: 1.59; 95% CI: 1.13–2.25), severe asthma (aOR: 1.34; 95% CI: 1.23–1.46), asthma ever (aOR: 1.47; 95% CI: 1.13–1.92), severe eczema (aOR: 1.51; 95% CI: 1.16–1.96), severe rhino-conjunctivitis (aOR: 1.54; 95% CI: 1.18–2.00) and rhino-conjunctivitis (aOR: 1.21; 95% CI: 1.15–1.27). The consumption of fast foods, especially hamburgers, ≥3 times/week, was more likely to be associated with severe asthma and current wheeze compared with the consumption of 1–2 times/week (both $P < 0.001$). In conclusion, the consumption of fast foods, particularly hamburgers, correlates to asthma in a dose–response pattern, which needs to be further validated in longitudinal and interventional studies.

Key words: allergy, asthma, fast food, wheeze.

Abbreviations: aOR, adjusted odds ratios; SES, state of social economy; TLR, toll-like receptor; URB, urbanization.

INTRODUCTION

The prevalence of asthma and atopic diseases such as eczema (atopic dermatitis), allergic rhinitis (pollen fever) and rhino-conjunctivitis has drastically increased over recent decades. These diseases have unclear aetiology and place a significant burden on the health-care system, as well as reducing the quality of life of patients. The factors driving increased prevalence remain unclear.[1,2]

With adoption of westernized lifestyles, consumption of 'fast foods' has increased.[3] Fast foods, first popularized in the 1950s in America, are typically foods sold in restaurants or stores with preheated or precooked ingredients and served to customers in a packaged form for takeaway.[4] Fast foods are typically calorically dense, high in refined carbohydrates, sodium, sugar, cholesterol, additives such as preservatives and colourants, with high concentrations of saturated fat.[5] Hence, it has been hypothesized that the consumption of fast foods may exacerbate the development and progression of asthma and allergic diseases.[6] However, the data available to date are heterogeneous, with some, but not all studies, reporting that asthma and allergic diseases are associated with the consumption of fast foods.[7–23]

Hence, the aim of this study was to determine whether the consumption of fast foods is related to asthma and other allergic diseases. We further aimed to explore the dose–response of the consumption of fast foods to asthma/wheeze, the differential effects of

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specific types of fast foods consumption, such as hamburgers, carbonated soft drink and takeaway foods on asthma/wheeze and the differential effects of fast food consumption on asthma and wheeze in countries according to income level.[24]

METHODS

This study was registered with PROSPERO, number CRD42016035873, which was performed and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) and the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines.[25] No ethics approval was necessary.

Search strategy and selection criteria

This study was carried out in OVID by searching databases, including MEDLINE (1946 to February week 2, 2018), EMBASE (1974 to 16 February 2018) and Cochrane Central Register of Controlled Trials (CENTRAL) (January 2018). Medical Subject Headings (MeSH) was used to construct the search terms, together with keywords from related literature.[26–29] The databases were conducted by search strategy related to fast foods, asthma/wheeze and allergic diseases and the search criteria can be found in Appendix S1 in Supplementary Information. Unpublished studies were also investigated through searching abstracts in the databases mentioned above. Reference lists of review articles were searched to identify other potentially eligible studies. Only English articles were included and there was no limitation on year of publication or publication status. Studies were included if they were cohort, cross-sectional or case–control studies exploring whether fast food consumption was related to asthma or other allergic diseases with available data presented as odds ratios (OR). After exclusion of duplicates, two researchers (C.S.W. and J.W.) reviewed the full text of all citations with titles and abstracts that seemed to fit the criteria for inclusion. Disagreements were solved by a third reviewer (G.W.). The number of studies rejected and the reasons for rejection were tracked. Funnel plots were used to appraise risk of bias across studies for some of the primary outcomes. The symmetry in the funnel plots was assessed visually.

Data extraction and quality assessment

We extracted the details, where available, from included studies, including author, publication year, study design, geographical location of the study, gender, age, sample size, frequency and the consumption of different kinds of fast foods, outcomes and OR related to these outcomes, and adjusted confounders for these OR. aOR of outcomes with 95% confidence interval (CI) were also extracted and the adjusted confounding factors were indicated. Otherwise, OR was calculated with the number of the exposed to the non-exposed ratio in the case group divided by the same ratio in the control group if absent in original studies.

Two researchers (C.S.W. and J.W.) applied the Newcastle-Ottawa Quality Assessment Scale[30] for case–control and cohort studies and Cross-Sectional/Prevalence Study Quality Scale[31] for cross-sectional studies to assess the quality of included articles.

Definition of fast foods

Fast foods are mass-produced foods prepared and served very quickly, with poor nutritional quality. In general, any foods with less preparation time can be regarded as fast foods, especially foods sold in a restaurant or store with preheated ingredients, and served to the customer in a packaged form for takeout. Furthermore, fast foods typically fall into the category of foods high in calories, total fat, saturated and trans fat, sugar, simple carbohydrates and sodium (salt). In this study, we did not set a pre-specified definition for fast foods.

Primary and secondary outcomes

The primary outcomes were defined as asthma and wheeze presented as current asthma, ever asthma, severe asthma, current wheeze and ever wheeze. The secondary outcomes included current rhinitis (rhinitis past 1 year), lifetime rhinitis (rhinitis ever), rhino-conjunctivitis, severe rhino-conjunctivitis, eczema, severe eczema and atopy. Primary and secondary outcomes are shown in Table 1.

Statistical analysis

Primary and secondary outcomes were treated as dichotomous variables and presented as OR with 95% CI. All OR with 95% CI were pooled based on study design and outcomes. In order to avoid counting participants more than one time, the method described by Greenland and Longnecker[32] was used if the raw data were available. Otherwise, the pooled effects of the consumption of fast foods on asthma and allergic diseases were estimated in accordance with the method described by Dong *et al.*[33]

If adjusted odds ratios (aOR) were indicated in the original studies, adjusted estimates were pooled using the generic inverse variance method. OR in each study were converted to natural logarithms. Standard errors (SE) from these logarithmic numbers and their corresponding 95% CI were calculated. We conducted the metan command in Stata to pool the ln OR across studies, used random-effects model as described by DerSimonian and Laird[34] with the estimate of heterogeneity being taken from the Mantel–Haenszel model, considering variation in effects due to differences in study populations and methods, and calculated the summary OR estimates with 95% CI.

Subgroup analyses were undertaken to assess the dose-dependent response of the consumption of fast foods to asthma/wheeze and other allergic diseases, with consumption frequency of fast food described as '<1 time per week, occasionally and never', '1–2 times per week' or '≥3 times per week'. In addition, differential effects of consumption of specific types of fast foods such as hamburgers, carbonated soft drink and takeaways on asthma/wheeze were examined. Furthermore,

Table 1 Primary and secondary outcomes defined in this study

Primary outcomes
Asthma
Current asthma[7,12,13,15,17,18,20,35]: either currently taking asthma medication or physician-diagnosed asthma or having had an asthma attack during the last 12 months
Ever asthma[14,19,35]: answering 'yes' to has you/your child ever had asthma?
Severe asthma[11,12,22]: Answering 'yes' to having four or more wheeze attacks or being awoken one or more nights per week due to wheeze, in the last 12 months
Wheeze
Ever wheeze[11,14]: parents were asked to answer 'yes' or 'no' to the question 'has your child ever had wheezing or whistling in the chest at any time'?
Current wheeze[7,11,14,22]: if the answer for 'ever wheeze' was 'yes', parents were asked to answer 'yes' or 'no' to the question 'has your child had wheezing or whistling in the chest in the past 12 months?'
Secondary outcomes
Current rhinitis (rhinitis past 1 year)[16]: the occurrence of any sneezing or a runny or blocked nose apart from common cold or the flue in the past 12 months
Lifetime rhinitis (rhinitis ever)[16]: the occurrence of any sneezing or a runny or blocked nose apart from common cold or the flue ever
Rhino-conjunctivitis[11,12,16,22]: answering 'yes' to the question 'has your child has a problem with sneezing or a runny or blocked nose or itchy watery eyes when they did not have a cold or flu?' and 'in the past 12 months, has this nose problem been accompanied by itchy watery eyes?'
Severe rhino-conjunctivitis[11]: having itchy watery eyes and who answered 'a lot' to their nose problems interfering with their daily activities, in the last 12 months
Eczema[8,11,19,22]: has your child had this itchy rash at any time in the past 12 months? And 'has this itchy rash at any time affected any of the following places: The folds of the elbows, behind the knees, in front of the ankles, under the buttocks, or around the neck, ears or eyes?'
Severe eczema[11,22]: having sleep disturbance one or more times per week due to symptoms of eczema, in the last 12 months
Atopy[7,14,18,19]: a positive reaction was defined as a mean wheal diameter of 3 mm or greater to any allergen, including cat, dog, pollen allergy

effects of the consumption of fast foods on asthma/wheeze in countries of different income level were determined, with countries classified according to World Bank criteria.[24] Statistical analysis was conducted with Stata 11.0 (Stata Corp. LP, College Station, TX, USA) and a two-sided $P < 0.05$ was considered as significant.

RESULTS

Studies included, characteristics and quality assessment

Figure S1 in Supplementary Information shows the flowchart for screening studies. The primary search strategy initially yielded 4138 citations from the OVID system. Of these, we identified 16 studies included in this systematic review and meta-analysis. Table 2 indicates that definitions of fast foods varied across all included studies. Table 3 shows the key characteristics of the 16 studies included in this analysis, published from 2001 to 2015, including 13 cross-sectional studies[7–9,11,12,14,16–19,21,22,35] and 3 case–control studies.[13,15,20] Sample size ranged from 144 to 500 827. One study included females only, while the remaining included both sexes. Two studies were undertaken in multi-centres and others were conducted in Colombia, Canada, Japan, China (Mainland and Taiwan), New Zealand, India, Spain, Saudi Arabia, Sweden, Turkey and Australia. All studies had primary or secondary outcomes relevant to this systematic review. Three case–control studies,[13,15,20] with a total sample size of 1326, investigated the association between the consumption of fast foods and asthma/wheeze. Four cross-sectional studies[9,17,21,35] with a total of 54 314 subjects researched the association between the consumption of fast foods and asthma/wheeze. Two cross-sectional studies[8,16] (total of 23 028 participants) only studied the consumption of fast foods and atopy and the remaining seven cross-sectional studies[7,11,12,14,18,19,22] (total of 530 678 participants) analysed the association between both asthma/wheeze and allergy and the consumption of fast foods. We intended to estimate heterogeneity and find publication bias with the use of funnel plots. However, considering the insufficient numbers of studies, this was not performed. The quality scores were 5.33 ± 1.16 in the case–control studies[13,15,20] and 5.69 ± 1.55 in the cross-sectional studies[7–9,11,12,14,16–19,21,22,35] (Tables S1 and S2 in Supplementary Information).

Primary outcomes

Primary and secondary outcomes were pooled using the highest category in fast food consumption described as following. Associations between the consumption of fast foods and asthma/wheeze are shown in Figure 1. The pooled aOR from three case–control[13,15,20] and six cross-sectional studies[7,12,17–19,21] indicated the consumption of fast foods was significantly related to current asthma (aOR: 1.58; 95% CI: 1.17–2.13 and aOR: 1.58; 95% CI: 1.10–2.26, respectively). Furthermore, severe asthma was associated with the consumption of fast foods[22] (aOR: 1.34; 95% CI: 1.23–1.46). The consumption of fast foods was associated with asthma ever (aOR: 1.36; 95% CI: 1.06–1.75) in three cross-sectional studies.[14,19,35] The consumption of fast foods increased the risk of current wheeze in five cross-sectional studies[7,9,14,22,35] (aOR: 1.21; 95% CI: 1.16–1.27) and wheeze ever in one cross-sectional study[14] (aOR: 1.65; 95% CI: 1.07–2.52).

Secondary outcomes

Associations between the consumption of fast foods with other allergic diseases are shown in Table S3 in Supplementary Information. Fast food consumption was significantly related to physician-diagnosed allergic rhinitis (pollen fever)[16,18] (OR: 1.43; 95% CI: 1.05–1.95), severe eczema[22] (aOR: 1.51; 95% CI: 1.16–1.96), rhino-

Table 2 Definitions of fast foods in included studies

Studies included	Definitions of fast foods
Kim *et al.*[7]	Fast food such as hamburgers
Suárez-Varela *et al.*[8]	Not described in detail
Wood *et al.*[9]	Not described in detail
Cepeda *et al.*[11]	Fast foods usually include consumption of burgers and foods rich in simple sugars
Garcia-Marcos *et al.*[12]	Not described in detail
Lawson *et al.*[13]	Fast food/soft drink consumption group
Wickens *et al.*[14]	Fast food consumption (hamburgers, takeaways and fizzy drinks), takeaways include any prepared food paid for before it is eaten most likely hamburgers or deep-fried battered fish with chips (fries). A hamburger refers to a beef mince patty eaten in a bread roll, which may or may not be bought from a takeaway outlet
Mai *et al.*[15]	Not described in detail
Tamay *et al.*[16]	Not described in detail
Huang *et al.*[17]	Deep-frying is the common way of Chinese food preparation, and the survey question regarding deep-frying included, but was not limited to, fast foods
Takaoka and Norback[18]	Fast food including hamburgers and carbonated soft drinks
Norback *et al.*[19]	Fast food including hamburgers and carbonated soft drinks
Hijazi *et al.*[20]	Not described in detail
Awasthi *et al.*[21]	Burger/fast food
Ellwood *et al.*[22]	Fast food is rich in industrially hydrogenated vegetable fats such as margarines which are dietary sources of trans fatty acids
Nagel *et al.*[35]	Fast food is rich in industrially hydrogenated vegetable fats such as margarines and meat from ruminant animals, which are dietary sources of trans fatty acids

conjunctivitis[22] (aOR: 1.21; 95% CI: 1.15–1.27) and severe rhino-conjunctivitis[22] (aOR: 1.54; 95% CI: 1.18–2.00).

Subgroup analyses of primary outcomes

The effect of different levels of fast food consumption on asthma/wheeze is shown in Table 4. The consumption of fast foods 1–2 times/week was associated with severe asthma[22] (aOR: 1.09; 95% CI: 1.04–1.13) and current wheeze[11,22,35] (aOR: 1.07; 95% CI: 1.03–1.11). The consumption of fast foods ≥3 times/week was associated with asthma ever[35] (aOR: 1.42; 95% CI: 1.08–1.87), severe asthma[22] (aOR: 1.34; 95% CI: 1.23–1.46) and current wheeze[11,22,35] (aOR: 1.22; 95% CI: 1.16–1.28). The consumption of fast foods ≥3 times/week was associated with an increased risk of severe asthma (aOR: 1.34; 95% CI: 1.23–1.46 vs aOR: 1.09; 95% CI: 1.04–1.13; $P < 0.001$) and current wheeze (aOR: 1.22; 95% CI: 1.16–1.28 vs aOR: 1.07; 95% CI: 1.03–1.11; $P < 0.001$) in comparison to consumption 1–2 times/week (Fig. 2).

Analysis of the relationship between different types of fast food consumption and asthma/wheeze (Table S4 in Supplementary Information) revealed that the consumption of hamburgers was associated with current asthma[15] (aOR: 1.59; 95% CI: 1.13–2.25), severe asthma[22] (aOR: 1.34; 95% CI: 1.23–1.46), asthma ever[19,35] (aOR: 1.47; 95% CI: 1.13–1.92) and current wheeze[7,11,22,35] (aOR: 1.22; 95% CI: 1.16–1.28). The consumption of hamburgers ≥3 times/week was associated with an increased risk of severe asthma (aOR: 1.34; 95% CI: 1.23–1.46 vs aOR: 1.09; 95% CI: 1.04–1.13; $P < 0.001$) and current wheeze (aOR: 1.22; 95% CI: 1.16–1.28 vs aOR: 1.07; 95% CI: 1.03–1.11; $P < 0.001$) in comparison to consumption of 1–2 times/week. In terms of high or middle-income countries, the consumption of fast foods was associated with current asthma in case–control studies[13,15,20] and cross-sectional studies[7,12,17,18] (aOR: 1.58; 95% CI: 1.17–2.13 and aOR: 1.44; 95% CI: 1.00–2.11, respectively), severe asthma[12] (aOR: 1.09; 95% CI: 1.04–1.13) and wheeze ever[14] (aOR: 1.65; 95% CI: 1.07–2.52) in high-income populations (Table S5 in Supplementary Information). In middle-income countries, the consumption of fast foods was associated with current asthma[21] (aOR: 2.89; 95% CI: 1.40–5.96) and current wheeze[11] (aOR: 1.74; 95% CI: 1.30–2.34).

Subgroup analyses for secondary outcomes are provided as Appendix S2 in Supplementary Information.

DISCUSSION

To our knowledge, this is the first systematic review and meta-analysis to investigate the relationship between the consumption of fast foods and asthma/wheeze and other allergic diseases. Our study indicated that the consumption of fast foods significantly correlates with current/severe/ever asthma, current/ever wheeze, physician-diagnosed allergic rhinitis (pollen fever), (severe) rhino-conjunctivitis and severe eczema. In terms of different types of fast food consumption, hamburger, but not takeaway or carbonated soft drink intake, was associated with severe/ever asthma, current wheeze, (severe) rhino-conjunctivitis and severe eczema. Furthermore, we determined that the consumption of fast food, especially hamburgers, correlates to severe/current asthma in a dose–response pattern. In addition, these relationships exist in both high- or middle-income populations.

In recent decades, fast foods have become an important component of the diet, especially in westernized, high-income countries. Fast foods consumption is associated with poor diet quality, high caloric intake, overweight and obesity in children and adolescents.[29,36–40] Overweight–obesity is an independent risk for asthma and allergic sensitization. After performing the sensitivity analyses for included studies with adjustment for BMI, we found that the positive association between the consumption of fast foods and current asthma (aOR: 0.85; 95% CI: 0.48–1.52), ever asthma (aOR: 1.09; 95% CI: 0.7–1.69) and current

Table 3 Characteristics of included studies

Author (year)	Settings/ countries	Study design	Sample size	Age	Gender	Exposure(s)	Outcomes	Findings	Adjusted confounders	Quality assessment scores
Kim *et al.* (2005)[7]	Sweden	Cross-sectional	*N* = 1014	5–14 years, mean age was 9 years	Girls: 51% and boys: 49%	Hamburgers	Current asthma, current wheeze and atopic sensitization	No statistical associations between the consumption of fast foods and asthma/ wheeze or atopic sensitization were found	Age, gender, and all other dietary factors at the same time (type of fat and other dietary factors)	8
Suárez-Varela *et al.* (2010)[8]	Spain	Cross-sectional	*N* = 13 153	6–7 years	—	Fast foods	Eczema	No association between the consumption of fast foods and atopic dermatitis	Gender, obesity, exposure to tobacco smoke in the first year of life, younger and older siblings, and exercise	5
Wood *et al.* (2015)[9]	Australia	Cross-sectional	*N* = 144	12–18 years	—	Takeaway	Wheeze	No associations between food intake and self-reported wheeze were observed	Age, sex and length of time in Australia	7
Cepeda *et al.* (2015)[11]	Colombia	Cross-sectional	*N* = 3209	6–7 years	Male: 1521 (47.3%), female: 1688 (52.7%)	Fast foods/ burgers	Current wheeze, rhino-conjunctivitis and eczema	Intake of fast foods increases the risk of eczema and wheeze	Maternal education level, current maternal smoking, maternal smoking during the first year of life and physical activity of the child	5
Garcia-Marcos *et al.* (2007)[12]	Spain	Cross-sectional	*N* = 22 038	6–7 years	—	Fast foods	Current asthma, severe asthma and rhino-conjunctivitis	Fast food intake was a risk factor for current severe asthma	Sex, obesity, maternal smoking, siblings and exercise	7
Lawson *et al.* (2013)[13]	Canada	Case–control	208 controls and 87 cases	6–18 years	—	Fast foods/ soft drink	Current asthma or wheeze	There was a trend towards an increased risk of asthma or wheeze associated with high fast foods/pop consumption	Sex, presence of a home air filter, maternal smoking during pregnancy, bare floor in the bedroom in the first year of life, age group, season of testing, tobacco smoke exposure, weight status, hard activity levels, fish and seafood consumption, and perceived weight status	6

Table 3 Continued

Author (year)	Settings/ countries	Study design	Sample size	Age	Gender	Exposure(s)	Outcomes	Findings	Adjusted confounders	Quality assessment scores
Wickens *et al.* (2005)[14]	New Zealand	Cross-sectional	*N* = 1321	10.1–12.5 years (mean age 11.4 years)	Female: 49.6%; male: 50.4%	Hamburgers, takeaway and fizzy drink	Ever asthma, ever wheeze, current wheeze and atopy	Frequent consumption of hamburgers showed a dose-dependent association with asthma symptoms	BMI (obese or overweight or underweight or normal), mother or father with history of allergic disease (asthma, eczema or hay fever), family size (as a continuous variable), birth weight (< or >2500 g), current smoking in the home, father's years of post-primary education (< or >5.5 years), frequency of hamburger, takeaway, fizzy drink, fish, fruit juice consumption (1+ times a week or less than once a week or never), frequency of raw or cooked vegetable, fruit, meat consumption (< twice a week or three to six times a week or > once a day), the interaction of gender with hamburgers and takeaways, exercise (≤ once a week or two to three times a week or four to six times a week or everyday), gender, ethnicity (Maori/Polynesian or European/other) and year born (1988 or 1989)	5
Mai *et al.* (2009)[15]	Canada	Nested case–control study	Cases: 243 allergist-diagnosed asthma, controls: 472 non-asthmatic controls	8–10 years	—	Burgers/ fast foods	Current asthma	Fast foods consumption is associated with asthma in children	First nations origin, exclusive breast feeding, sex, maternal asthma, location, overweight and family income	6

Table 3 Continued

Author (year)	Settings/ countries	Study design	Sample size	Age	Gender	Exposure(s)	Outcomes	Findings	Adjusted confounders	Quality assessment scores
Tamay *et al.* (2014)[16]	Turkey	Cross-sectional	*N* = 9875	6–7 years	Male: 50.7% female: 49.3%	Fast foods	Physician-diagnosed allergic rhinitis, rhinitis ever, current rhinitis, rhino-conjunctivitis, rhinitis ever and pollen allergy	The strong positive association between consumption of fast foods and allergic diseases	Gender, obesity, exposure to tobacco smoke in the first year of life, younger and older siblings and exercise	5
Huang *et al.* (2001)[17]	Taiwan	Cross-sectional	*N* = 1166	13–17 years, mean age was 14.7 years	582 males and 584 females	Deep-frying	Asthma	Deep-fried foods were associated with asthma	Two levels of urbanization	7
Takaoka and Norback (2008)[18]	Japan	Cross-sectional	*N* = 153	Mean age was 21 years	—	Hamburgers and carbonated soft drinks	Current asthma, cat or dog allergy, pollen allergy	The frequent consumption of fast foods and soft drinks could be risk factors for allergy	Age, current smoking and parental asthma/allergy	5
Norback *et al.* (2007)[19]	China	Cross-sectional	*N* = 2116	9–20 years (mean age 15 years)	Female: 1058 (50%); male: 1058 (50%)	Hamburgers and carbonated soft drinks	Ever asthma, eczema, pollen or cat allergy	Fast foods consumption may increase the risk for asthma	Model I: age and gender only, analysing each dietary variable separately; model II: age, gender, rural childhood, current urban residency, indoor painting, new floor materials, environmental tobacco smoke in the dwelling and all other dietary variables at the same time	4
Hijazi *et al.* (2000)[20]	Saudi Arabia	Case–control	114 cases with asthma and wheeze last 12 months, 202 controls without wheeze or asthma	Mean age: 12 years	—	Fast foods	Current asthma	The frequency of eating at a fast foods outlet was significantly related to being a current asthma.	NA	4
Awasthi *et al.* (2004)[21]	India	Cross-sectional	*N* = 3000	13–14 years, mean age: 13.34 years	1440 (48.1%) boys and 1560 (52%) girls	Fast foods	Current asthma	Fast food consumption increased the risk of asthma	Not described	3

Table 3 Continued

Author (year)	Settings/ countries	Study design	Sample size	Age	Gender	Exposure(s)	Outcomes	Findings	Adjusted confounders	Quality assessment scores
Ellwood *et al.* (2013)[22]	Multicentre	Cross-sectional	N_1 = 319 196; N_2 = 181 631	13–14 years; 6–7 years	—	Fast foods/ burgers	Current wheeze, severe asthma, (severe)rhino-conjunctivitis and (severe) eczema	Fast foods consumption may be contributing to the increasing prevalence of asthma, rhino-conjunctivitis and eczema in adolescents and children	Region, gender, language, gross national income, exercise, television viewing, maternal education and current maternal smoking	7
Nagel *et al.* (2010)[35]	Multicentre	Cross-sectional	N = 50 004	8–12 years	—	Burgers and fizzy drinks	Current wheeze and asthma ever	High burger consumption was associated with higher lifetime asthma prevalence	Age, sex, environmental tobacco smoke, parental atopy, exercise and number of siblings (0, 1–2, >3 siblings)	7

NA, not applicable.

wheeze (aOR: 1.08; 95% CI: 0.63–1.83) disappeared, while the association between the consumption of fast foods and current asthma (case–control design) (aOR: 1.58; 95% CI: 1.17–2.13) and ever wheeze (aOR: 1.65; 95% CI: 1.07–2.52) remained, which would be explained by BMI as a confounder or a reduced small sample size. It indicated that as one of the indispensable confounders, BMI might mediate the association between the consumption of fast foods and asthma.[41] Furthermore, the poor quality diet that develops when fast foods are regularly included in the diet introduces nutrient deficits that are likely to independently contribute to asthma development and progression.[42]

Poor quality diet is likely to contribute to the development and progression of asthma/wheeze via multiple mechanisms. For example, saturated fatty acids can activate toll-like receptors (TLR), leading to release of pro-inflammatory cytokines (TNF-α and IL-6) and Nuclear factor (NF)-κB-mediated innate immune responses which can contribute to chronic inflammatory diseases of the airways.[13,43–45] Indeed, our previous study[43] provided evidence that a high-fat meal exacerbates airway inflammation in asthma, with increased airway neutrophilia and TLR4 expression in induced sputum. In addition, the consumption of fast foods reduces the consumption of foods that are rich in protective nutrients, such as fruits and vegetables. Fruit and vegetables contain many phytochemicals that have anti-oxidative and anti-inflammatory properties. Hence a reduction in fruit and vegetable intake is likely to have an unfavourable impact on asthma prevalence/ management.[46] Indeed, we have previously shown that consumption of a low fruit and vegetable diet leads to a reduced risk of exacerbation in adults with asthma.[47] Hence, the associations that we have seen between the consumption of fast foods and asthma/wheeze are biologically plausible.

Our analysis has considered the effects of the quality and heterogeneity of included studies. Given the relatively high heterogeneity and bias, evidence from cross-sectional or case–control studies was graded as low quality. Study design of the cross-sectional and case–control studies included in this meta-analysis, based on questionnaire surveys and self-report, can lead to recall bias and information bias giving rise to misclassification. This may weaken the quality of evidence and, thus, causal association between the consumption of fast foods and asthma/wheeze and other allergic diseases cannot be confirmed. In terms of the quality of the included studies, intriguingly, our subgroup analyses from relative high-quality studies confirmed these associations except for current asthma. Furthermore, the heterogeneity in the included studies is due to potential confounding factors such as age, gender, exercise, television viewing, maternal education, current smoking, environmental tobacco smoke in the dwelling, gross national income, current urban residency, indoor painting, new floor materials, region, language, parental atopy, exercise, parental asthma/allergy rural childhood and number of siblings (Table 3). When these confounding factors were adjusted, the heterogeneity was significantly reduced.[7,9,12,14,16–19,21,22,35] Our sensitivity analyses with regards to studies adjusting for less than two common confounders including BMI, the state of social

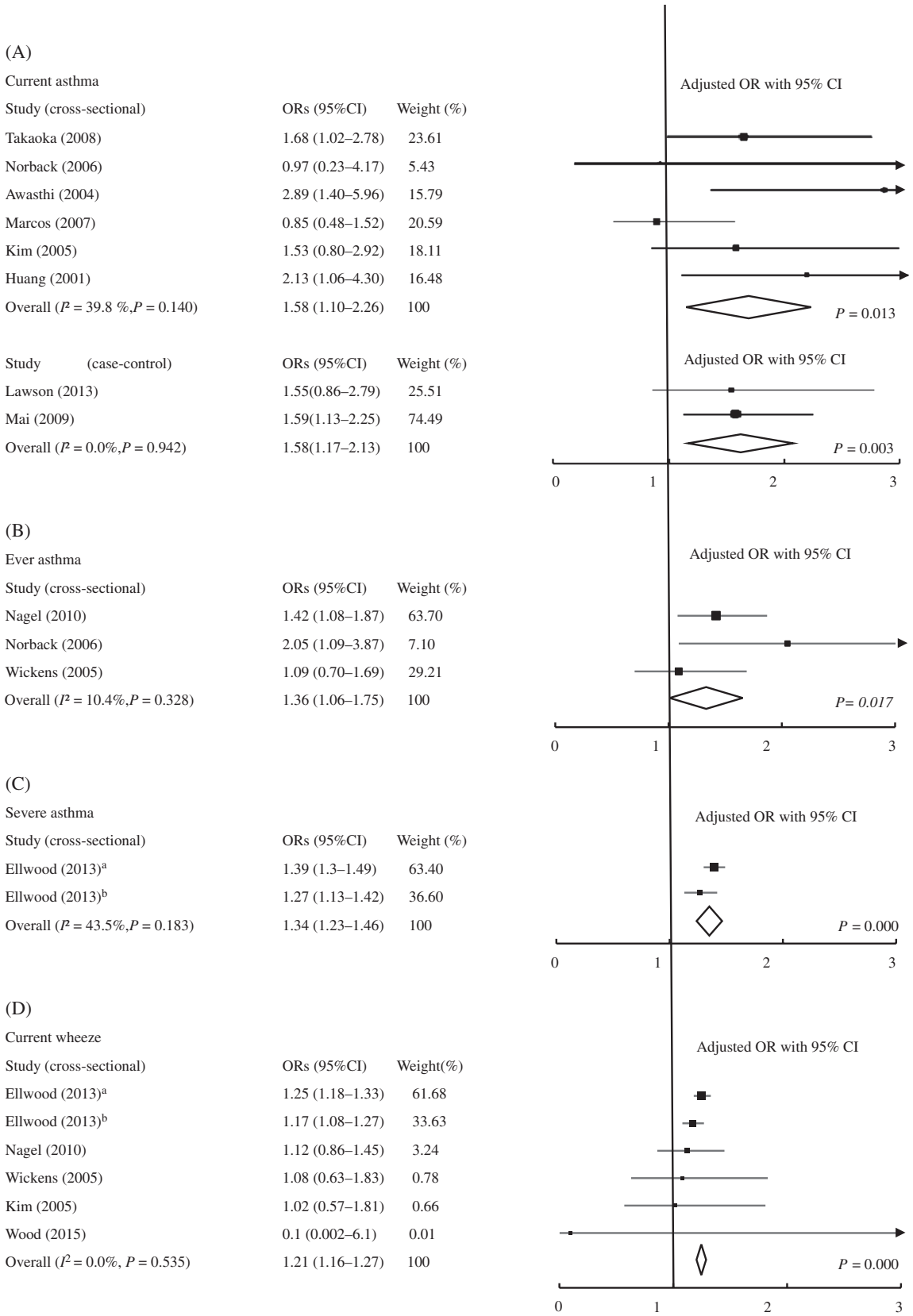

Figure 1 Associations of the consumption of fast foods with current asthma (A), asthma ever (B), severe asthma (C) and current wheeze (D). (A) Subjects aged 13–14 years and (B) subjects aged 6–7 years.

Table 4 Effects of different frequency of the consumption of fast foods on asthma/wheeze and other allergic diseases in cross-sectional studies

Outcomes	Number of studies	Number of subjects	Crude OR (95% CI)		aOR (95% CI)	
The consumption of fast foods 1–2 times/week						
Current asthma	1[12]	22 038	NA	NA	1.04 (0.90–1.21)	NA
Asthma ever	1[35]	50 004	NA	NA	1.04 (0.90–1.20)	NA
Severe asthma	1[22]	500 827	NA	NA	1.09 (1.04–1.13)	I^2 = 0.0%, P = 0.832
Current wheeze	3[11,22,35]	554 040	1.06 (1.00–1.13)	I^2 = 16.1%, P = 0.304	1.07(1.03–1.11)	I^2 = 14.8%, P = 0.309
Physician-diagnosed allergic rhinitis (pollen fever)	1[16]	9875	1.46 (1.19–1.78)	NA	NA	NA
Eczema	2[11,22]	504 036	1.04 (0.99–1.09)	I^2 = 0.00%, P = 0.919	1.04 (1.00–1.08)	I^2 = 0.00%, P = 1
Life time rhinitis (rhinitis ever)	1[16]	9875	0.90 (0.80–1.02)	NA	0.91 (0.68–1.22)	NA
Current rhinitis (rhinitis past 1 year)	1[16]	9875	0.98 (0.80–1.20)	NA	NA	NA
Rhino-conjunctivitis	4[11,12,16,22]	535 949	1.05 (1.01–1.09)	I^2 = 0.00%, P = 0.976	1.03 (0.98–1.08)	I^2 = 52.7%, P = 0.146
Severe rhino-conjunctivitis	1[22]	5 000 827	NA	NA	0.97 (0.78–1.21)	I^2 = 79.6%, P = 0.027
Severe eczema	1[22]	5 000 827	NA	NA	1.10 (0.95–1.27)	I^2 = 62.8%, P = 0.101
The consumption of fast foods ≥ 3 times/week						
Current asthma	1[12]	22 038	NA	NA	0.85 (0.48–1.52)	NA
Asthma ever	1[35]	50 004	NA	NA	1.42 (1.08–1.87)	NA
Severe asthma	1[22]	500 827	NA	NA	1.34 (1.23–1. 46)	I^2 = 43.5%, P = 0.183
Current wheeze	3[11,22,35]	554 040	1.32 (1.08–1.61)	I^2 = 66.7%, P = 0.05	1.22 (1.16–1.28)	I^2 = 3.1%, P = 0.356
Rhino-conjunctivitis	4[11,12,16,22]	535 949	1.21 (1.15–1.28)	I^2 = 0.00%, P = 0.786	1.21 (1.15–1.27)	I^2 = 0.0%, P = 0.872
Severe rhino-conjunctivitis	1[22]	500 827	NA	NA	1.54 (1.18–2.00)	I^2 = 72.2%, P = 0.058
Severe eczema	1[14]	1321	NA	NA	1.51 (1.16–1.96)	I^2 = 76.6%, P = 0.039
Physician-diagnosed allergic rhinitis (pollen fever)	1[16]	9875	1.28 (0.85–1.93)	NA	NA	NA
Current rhinitis (rhinitis past 1 year)	1[16]	9875	1.08 (0.73–1.60)	NA	NA	NA
Lifetime rhinitis (rhinitis ever)[1]	1[16]	9875	1.28 (0.85–1.93)	NA	1.08 (0.73–1.60)	NA
Eczema[2,3]	2[11,22]	504 036	1.19 (1.11–1.28)	I^2 = 0.0%, P = 0.563	1.12 (0.97–1.29)	I^2 = 83%, P = 0.015

aOR, adjusted odds ratios; NA, not available.

economy (SES), urbanization (URB), smoking and parental allergy, indicated that these confounders might modify the associations of consumption of fast foods with current asthma (aOR: 1.19; 95% CI: 0.72–1.98) and current wheeze (aOR: 0.77; 95% CI: 0.18–3.39). However, the statistical approaches used were not consistent enough to make definitive conclusions about the effect of each of these variables. In addition, eliminating the study by Ellwood *et al.*,[22] which has a large sample size, did not change the associations observed, except for current wheeze.

This analysis is limited by the lack of standard definition for fast foods in the included studies,[48] although a formal survey questionnaire was designed in most of included studies and investigators asked subjects to answer the detailed questions on fast food intake. Variation in the definition of fast foods would contribute to the heterogeneity across included studies. Therefore, we only explored the initial relationship between the consumption of fast foods and asthma. Another limitation is the deficiency of temporal data, a characteristic of cross-sectional studies, which makes it impossible to demonstrate a causal effect of the consumption of fast foods on study outcomes. Furthermore, although the difference in dietary habits of adults versus children may exist, the association between the consumption of fast foods and diseases was not analysed by age group. In addition, the definitions of asthma/wheeze and other allergic diseases, as primary and secondary outcomes in included studies, were somewhat different,

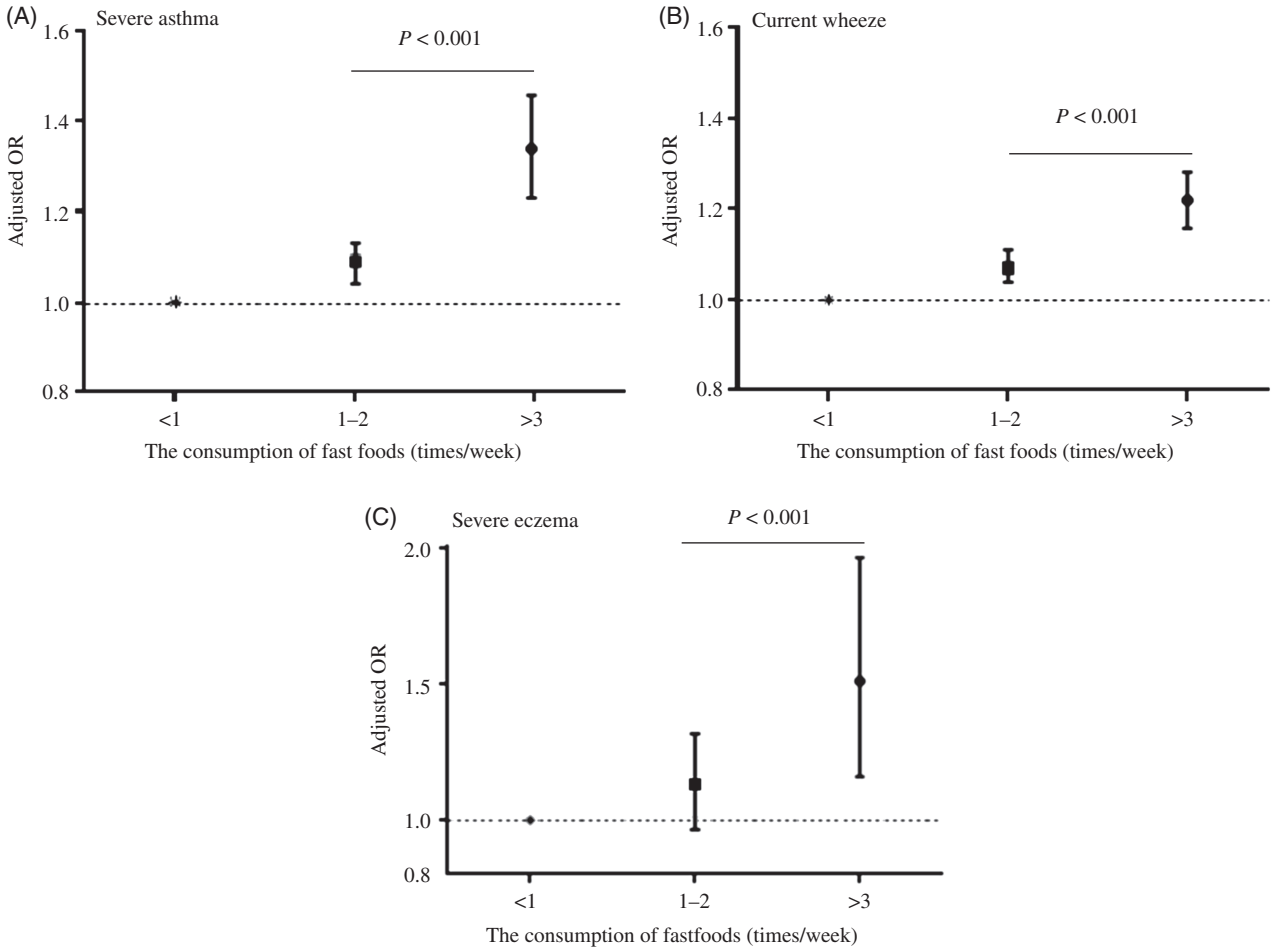

Figure 2 The dose–response relationships of the consumption of fast foods (times/week) with severe asthma (A), current wheeze (B) and severe eczema (C).

and in some cases, lacking objective measures. Finally, confounders such as BMI, SES, URB, smoking and parental allergy might modify the associations between the consumption of fast foods and asthma and allergic diseases, thus influencing our results.

While the current study has some limitations as described above, bias has been reduced by our analysis strategy. First, all OR with 95% CI in primary and secondary outcomes were separately pooled based on study design. Second, aOR were used to reduce the effects of confounding factors on outcomes. Third, we have strengthened our observations by demonstrating a dose-dependent response of the consumption of fast foods on asthma/wheeze. Fourth, subgroup analysis was undertaken to consider the effects of different types of fast foods consumption, including hamburgers, carbonated soft drinks, takeaways and deep-frying. Fifth, although the definitions of asthma and other allergic diseases are subjective, the repeatability and predictive validity have previously been demonstrated. Parameter estimates (95% CI) of specificity and sensitivity between response to questionnaires and physician diagnosis of current asthma were 0.97 (0.90, 0.99) and 0.80 (0.58, 0.93) for adult, 0.81(0.76, 0.86) and 0.85 (0.73, 0.93) for children.[49,50] Lastly, results were reported based on the highest fast food consumption frequency, which gave rise to possibly overstating the association between the consumption of fast foods and asthma/allergic diseases. Nevertheless, it can be explained by the extent of exposure in terms of a dose–response effect.

In conclusion, our study, for the first time, has systematically assessed the relationship between the consumption of fast foods and asthma/wheeze and other allergic diseases. It has demonstrated that the consumption of fast foods, in particular hamburgers, correlates to asthma in a dose–response manner. Relationships between the consumption of fast foods and asthma/wheeze exist in high- or middle-income populations. Given the quality of studies included, further longitudinal cohort and intervention studies are needed to confirm these relationships and identify causal associations between the consumption of fast foods and asthma/wheeze and other allergic diseases, which could in some degree explain the increasing prevalence of these diseases and offer a potential intervention strategy.

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Supplementary Information

Additional supplementary information can be accessed via the *html* version of this article at the publisher's website.

Appendix S1. Search criteria for MEDLINE, EMBASE and CENTRAL.
Appendix S2. Subgroup analyses of secondary outcomes.
Figure S1. Flowchart of study selection.
Table S1. Methodological quality assessment for included studies with cross-sectional design.
Table S2. Methodological quality assessment for included studies with case–control design.
Table S3. Associations of the consumption of fast foods with other allergic diseases in cross-sectional studies.
Table S4. Analysis of the associations of the consumption of different kinds of fast foods with asthma/wheeze and other allergic diseases.
Table S5. Analysis of the associations of the consumption of fast foods with asthma/wheeze and other allergic diseases according to income of countries.

