EAACI GUIDELINES
Food Allergy and Anaphylaxis

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The European Academy of Allergy and Clinical Immunology, EAACI, is a non-profit organisation active in the field of allergic and immunologic diseases such as asthma, rhinitis, eczema, occupational allergy, food and drug allergy and anaphylaxis. EAACI was founded in 1956 in Florence and has become the largest medical association in Europe in the field of allergy and clinical immunology. It includes over 7800 members from 121 countries, as well as 47 National Allergy Societies.
To all the members of EAACI
and to our patients
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Food allergy is affecting the lives of millions of people around the world and is on the rise. The emergency and life-threatening nature of the disease with the burden of anaphylaxis and its increasing prevalence, makes it a major public health problem. Governments and the general public are expected to face increasing direct and indirect costs, due to its major effects on life style and quality of life. Unfortunately, a high number of unmet needs remain to be resolved because of gaps in current scientific knowledge in pathophysiology, preventive measures, standardization and patient care.

To tackle this huge global health problem, the EAACI decided to develop “EAACI Food Allergy and Anaphylaxis Guidelines”. We aimed to develop a comprehensive set of documents on food allergy and severe allergic reactions, embracing all stakeholders. Our efforts during the guidelines development enabled us to establish a working model involving all related sections and interest groups of our Academy and helped to develop a network of affiliated scientists, clinicians and patient organizations across the globe.

The guidelines were drafted by more than 70 expert authors from all around the world. All sections of the EAACI, Pediatrics, Immunology, Dermatology, Asthma, Junior Members and Affiliates and Interest Groups of Food Allergy, Allied Health, Allergy Diagnosis, Insect Venom Hypersensitivity, and Primary Care were directly involved in their development. Twenty one international patient organizations were involved from the beginning within the frame of EAACI Patient Organization Committee. The European Society of Pediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN), the European Society of Emergency Medicine (EuSEM), and the Association for Teacher Education in Europe (ATEE) were involved as international associations. A panel of 30 international experts has reviewed the Guidelines, which have also gone through public consultation.

We would like to thank all of the authors and organizations for their contributions, the EAACI Executive Committee Members of the last two terms, and particularly Prof. Antonella Muraro for her leadership and commitment. We are certain that this effort, followed by a structured dissemination program will have a major impact on improving the wellbeing of patients with food allergy in Europe and around the world.

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EAACI Past President

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<td>AAI</td>
<td>Adrenaline Auto-injector</td>
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<tr>
<td>ACE inhibitor</td>
<td>Angiotensin Converting Enzyme Inhibitor</td>
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<tr>
<td>AGREE II</td>
<td>Appraisal of Guidelines for REsearch &amp; Evaluation</td>
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<td>APT</td>
<td>Atopy Patch Test</td>
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<td>AQLO</td>
<td>Asthma Quality of Life Questionnaire</td>
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<td>BAT</td>
<td>Basophil Activation Test</td>
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<tr>
<td>BCG vaccine</td>
<td>Bacillus Calmette–Guérin vaccine</td>
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<td>BoT</td>
<td>Burden of Treatment</td>
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<tr>
<td>BP</td>
<td>Blood Pressure</td>
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<td>CASP</td>
<td>Critical Appraisal Skills Programme</td>
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<td>CBT</td>
<td>Cognitive Behavioural Therapy</td>
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<tr>
<td>CCC</td>
<td>Concordance Correlation Coefficient</td>
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<tr>
<td>CI</td>
<td>Confidence Interval</td>
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<td>CRD</td>
<td>Component Resolved Diagnosis</td>
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<tr>
<td>DALY</td>
<td>Disability Adjusted Life Years</td>
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<tr>
<td>DBPCFC</td>
<td>Double-Blind, Placebo-Controlled Food Challenge</td>
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<tr>
<td>EAACI</td>
<td>European Academy of Allergy and Clinical Immunology</td>
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<td>ED</td>
<td>Emergency Departments</td>
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<td>EIA</td>
<td>Exercise-Induced Anaphylaxis</td>
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<td>EoE</td>
<td>Eosinophilic Esophagitis</td>
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<tr>
<td>FA</td>
<td>Food Allergy</td>
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<tr>
<td>FAIM</td>
<td>Food Allergy Independent Measure</td>
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<tr>
<td>FAQL-PB</td>
<td>Food Allergy Quality of Life Parental Burden</td>
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<tr>
<td>FAQLQ –PF</td>
<td>Food Allergy Quality of Life Questionnaire Parent Form</td>
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<td>FAQLQ-AF</td>
<td>Food Allergy Quality of Life Questionnaire Adult Form</td>
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<td>FAQLQ-CF</td>
<td>Food Allergy Quality of Life Questionnaire Child Form</td>
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<td>FAQLQ-TF</td>
<td>Food Allergy Quality of Life Questionnaire Teenager Form</td>
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<tr>
<td>FAQL-teen</td>
<td>Food Allergy Quality of Life Assessment Tool for Adolescents</td>
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<tr>
<td>FDEIA</td>
<td>Food-Dependent, Exercise-Induced Anaphylaxis</td>
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<tr>
<td>FIR</td>
<td>Food Information Regulation 1169/2011 EC</td>
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<tr>
<td>FPIES</td>
<td>Food Protein-Induced Enterocolitis Syndrome</td>
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<tr>
<td>GERD</td>
<td>Gastro-Esophageal Reflux Disease</td>
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<tr>
<td>GMP</td>
<td>Good Manufacturing Practice</td>
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<tr>
<td>GRADE</td>
<td>Grading of Recommendations Assessment, Development and Evaluation</td>
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<tr>
<td>HAO</td>
<td>Health-Related Quality of Life</td>
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<tr>
<td>ICDQ</td>
<td>Health-Related Quality of Life Questionnaire</td>
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<tr>
<td>ICC</td>
<td>Intraclass Coefficient</td>
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<tr>
<td>ICD</td>
<td>International Classification of Diseases codes</td>
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<tr>
<td>IgE</td>
<td>Immunoglobulin E</td>
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<tr>
<td>IgG4</td>
<td>Immunoglobulin G4</td>
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<tr>
<td>IM</td>
<td>Independent Measure</td>
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<tr>
<td>LR</td>
<td>Likelihood Ratio</td>
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<tr>
<td>LTP</td>
<td>Lipid Transfer Proteins</td>
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<tr>
<td>MCID</td>
<td>Minimal Clinically Important Difference</td>
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<tr>
<td>MID</td>
<td>Minimal Important Difference</td>
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<tr>
<td>NIAID</td>
<td>National Institute of Allergy and Infectious Diseases</td>
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<tr>
<td>NNT</td>
<td>Number Needed to Treat</td>
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<td>NPV</td>
<td>Negative Predictive Value</td>
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<td>NSAID</td>
<td>Non Steroidal Anti-Inflammatory Drugs</td>
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<td>OAS</td>
<td>Oral Allergy Syndrome</td>
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<tr>
<td>OFC</td>
<td>Oral Food Challenge</td>
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<tr>
<td>PCP</td>
<td>Personalized Care Plan</td>
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<td>PEF</td>
<td>Peak Expiratory Flow</td>
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<tr>
<td>PEMP</td>
<td>Personalized Emergency Management Plan</td>
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<tr>
<td>PFA-QL</td>
<td>Paediatric Food Allergy Quality of Life Questionnaire</td>
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<tr>
<td>PPV</td>
<td>Positive Predictive Value</td>
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<tr>
<td>PRISMA</td>
<td>Preferred Reporting Items for Systematic Reviews and Meta-Analyses</td>
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<tr>
<td>QALY</td>
<td>Quality-Adjusted Life Years</td>
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<tr>
<td>QOL</td>
<td>Quality of life</td>
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<tr>
<td>RCT</td>
<td>Randomised Controlled Trial</td>
</tr>
<tr>
<td>RQLQ</td>
<td>Rhinoconjunctivitis Quality of Life Questionnaire</td>
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<tr>
<td>sIgE</td>
<td>Specific Immunoglobulin E</td>
</tr>
<tr>
<td>SLIT</td>
<td>Sublingual Immunotherapy</td>
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<tr>
<td>SPT</td>
<td>Skin Prick Test</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>US</td>
<td>United States</td>
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<tr>
<td>VIT</td>
<td>Hymenoptera Venom Immunotherapy</td>
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</table>
The lack of public understanding of food allergy is hugely affecting the recognition of the disease and of its impact at the community level including the quality of life and costs issues. In addition, very few people are aware that a severe allergic reaction, such as anaphylaxis, can result in death. As a consequence, anaphylaxis is still frequently mismanaged, both by patients and healthcare professionals. There is a need for better education of health professionals and the public. As part of its Mission, the European Academy of Allergy and Clinical Immunology (EAACI) initiated a project on food allergy and anaphylaxis in 2012 which combined a public campaign with the development of scientific outputs and guidelines, intended to translate best science into best practice. The EAACI Food Allergy and Anaphylaxis Guidelines are devoted to improving the overall care of the patient suffering from food allergy and anaphylaxis. The aim has been to provide scientific update on the latest evidence in the field establishing a platform where all the stakeholders can share their knowledge and ultimately create links and networks around the patients and their families.

The EAACI Food Allergy and Anaphylaxis Guidelines group has undertaken this unprecedented project over the last 2 years. Within the group, six task forces have comprehensively reviewed food allergy and anaphylaxis in children, adolescents and adults. The activity has been grounded in evidence with the use of comprehensive systematic reviews and, where appropriate, meta-analyses of the literature. The work was carried out by a wide range of health care professionals and scientists along with the involvement of both patient groups and regulators.

This book represents a compilation of the output of the EAACI Food Allergy and Anaphylaxis Guidelines Group. The first section covers food allergy. It is based on three systematic reviews covering the epidemiology, the diagnosis and the management of food allergy; these are presented in four chapters (1.1, 1.2, 1.3, 1.4) that summarise the evidence in these areas. These data have been used to generate the food allergy diagnosis and management guidelines (Chapter 1.5). The second section focuses on prevention. A systematic review of the food allergy prevention literature (Chapter 2.1) was used to develop evidence based prevention guidelines for food allergy (Chapter 2.2). The third section focuses on quality of life in food allergy. A systematic review of the literature (Chapter 3.1) looked for food allergy quality of life instruments that were appropriately developed and validated. These data were used to generate food allergy quality of life guidelines (Chapter 3.2). The fourth section focuses on anaphylaxis. It is imbedded within two systematic reviews of the literature, the first focuses on the epidemiology (Chapter 4.1) and the second on the management of anaphylaxis (Chapter 4.2). These data were then combined to generate guidelines for anaphylaxis (Chapter 4.3). Section 5 focuses on the community where many reactions to foods take place. The last section focuses on the food industry and how it might help to reduce the burden associated with food allergy and anaphylaxis. Each of the sections also looks forward, highlighting which research gaps should be prioritised and what public health interventions are required to minimise the burden of food allergy and anaphylaxis.

All the chapters in this book represent manuscripts that have been published in the journal Allergy. Wiley has kindly given permission to reproduce these in this book. Supplementary material associated with each of the guidelines chapters can be found as appendices at the end of each chapter. The supplementary material for the other chapters is available online via the EAACI website.

This book represents the work of over 70 individuals. The EAACI food allergy and anaphylaxis guidelines would not have been possible without their hard work and dedication to this activity. We would particularly like to thank the steering group leads: Ioana Agache, Carsten Bindslev-Jensen, Vicky Cardona, Anthony Dubois, Susanne Halken, Karin Hoffmann-Sommergruber, Lars Poulsen, and Thomas Werfel who ensured that the guidelines remained on track during
their development. We are hugely indebted to Aziz Sheik for leading the methodology team who were fundamental to synthesising the evidence base for this project. We would particularly like to thank Sukhmeet Panesar who project managed this element of the project. We thank all the experts, who kindly reviewed the draft manuscripts and helped us to develop them into the final documents reproduced in this book, and the patient’s group representatives who were heavily involved in developing each of the chapters; they are listed at the beginning of each chapter.

We are also very grateful for all the EAACI members who responded to our call for comments about the draft documents in June 2013. The guidelines group are extremely appreciative of the support of our past President Cezmi Akdis and our current President Nikos Papadopoulos for this activity, as well as for the support of all the other Executive Committee members. We would like to thank the EAACI Headquarters staff for their support of this project. Finally we would also like to express our appreciation of our personal assistants, Lynn Reeves in Southampton and Catherine Crowley in Padua.

It has been an exciting journey. However, having scientifically robust and thoroughly researched guidelines is just the beginning; it is their application in health professionals’ daily work that will make a real and tangible difference to clinicians and their patients.

Antonella Muraro and Graham Roberts
Editors
SECTION 1

FOOD ALLERGY DIAGNOSIS AND MANAGEMENT
1.1 THE EPIDEMIOLOGY OF FOOD ALLERGY IN EUROPE
SYSTEMATIC REVIEW AND META-ANALYSIS

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**Background:** Food allergy (FA) is an important atopic disease although its precise burden is unclear. This systematic review aimed to provide recent, up-to-date data on the incidence, prevalence, time-trends, and risk and prognostic factors for FA in Europe.

**Methods:** We searched four electronic databases, covering studies published from January 1, 2000 to September 30, 2012. Two independent reviewers appraised the studies and qualified the risk of bias using the Critical Appraisal Skills Programme tool.

**Results:** Seventy-five eligible articles (comprising of 56 primary studies) were included in a narrative synthesis and 30 studies in a random-effects meta-analysis. Most of the studies were graded as at moderate risk of bias. The pooled lifetime and point prevalence of self-reported FA were 17.3% (95% CI 17.0-17.6) and 5.9% (95% CI 5.7-6.1), respectively. The point prevalence of sensitization to ≥ 1 food as assessed by specific-IgE was 10.1% (95% CI 9.4-10.8) and skin prick test 2.7% (95% CI 2.4-3.0), food challenge positivity 0.9% (95% CI 0.8-1.1). While the incidence of FA appeared stable over time, there was some evidence that the prevalence may be increasing. There were no consistent risk or prognostic factors for the development or resolution of FA identified, but sex, age, country of residence, familial atopic history, and the presence of other allergic diseases seem to be important.

**Conclusions:** Food allergy is a significant clinical problem in Europe. The evidence base in this area would benefit from additional studies using standardized, rigorous methodology; data are particularly required from Eastern and Southern Europe.

Epidemiology of food allergy in Europe: a review

BACKGROUND

During the past 50-60 years, the frequency of asthma and other atopic diseases, such as atopic eczema/dermatitis and allergic rhinitis, has increased in many Western countries. They now represent a substantial burden to healthcare systems and the society (1-5). Whilst the incidence of these diseases may have peaked in some settings (3), it has been suggested that the frequency of food allergy (FA) appears to have increased during the last 10-20 years (6-10), leading to the thought that FA may have different risk factors (6, 8).

Despite the suggested increasing frequency of FA and the attributed public health burdens (6-10), estimates of the actual incidence and prevalence are uncertain. Relatively few epidemiological studies have utilized the gold standard of diagnosis – the double-blind, placebo-controlled food challenge (DBPCFC) in defining FA (6, 8). Most frequency estimates have been based on lay perceptions or specific Immunoglobulin E (IgE) or skin prick test (SPT) sensitization to common food allergens. Both self-perception and allergic sensitization are known to substantially overestimate the actual frequency of FA (11-13).

This systematic review is one of seven inter-linked evidence syntheses that have been undertaken to provide a state-of-the-art European synopsis of the current evidence base in relation to epidemiology, prevention, diagnosis and clinical management, and impact on quality of life. They have been used to inform clinical recommendations in the EAACI Guidelines for Food Allergy and Anaphylaxis. The aims of the systematic review were to: (1) estimate the frequency of FA; (2) investigate time-trends; and (3) identify potential risk and prognostic factors for the development of FA in Europe.

METHODS

Protocol and registration

The protocol of this review has been published previously (14) and it is registered with the International Prospective Register of Systematic Reviews (PROSPERO; http://www.crd.york.ac.uk/prospero/, reference CRD42013003704).

Search strategy

A highly sensitive search strategy was designed (see Box E1) to retrieve all articles combining the concepts of food allergy and epidemiology from electronic bibliographic databases. See online supplement for further details.

Inclusion and exclusion criteria

The following studies were included: systematic reviews and meta-analyses, cohort studies, cross-sectional studies, case-control studies and routine healthcare studies published in Europe between January 1, 2000 and September 30, 2012. These were chosen to ensure that the highest levels of European evidence were pooled based on the aims of the review. Reviews, discussion papers, non-research letters and editorials, case studies, and case series plus animal studies and all randomised controlled trials were excluded. See online supplement for further details.

Study selection

The titles of retrieved articles were checked by two independent consultant reviewers according to our selection criteria and categorized as: included, not included, and unsure. The abstracts of papers in the unsure category were retrieved and re-categorized as above after further discussion. Full text copies of potentially relevant studies were obtained and their eligibility for inclusion was independently assessed by two reviewers (BN and LH). Any discrepancies were resolved by consensus or a third reviewer (AS) arbitrated.

Risk of bias assessment

Risk of bias in the studies was independently carried out by two reviewers (BN and LH) using adapted relevant versions of the Critical Appraisal Skills Programme (CASP) tool (http://www.casp-uk.net/). An overall grading was assigned to each study based on the grading obtained from the various components of the study (i.e., the appropriateness of the study design for the research question, the risk of selection bias, exposure and outcome assessment). Discrepancies were resolved by consensus or a third reviewer (AS) arbitrated.

Analysis, synthesis and reporting

A customized data extraction form was developed and independently used to obtain relevant data from each study by two reviewers (BN and LH). Discrepancies
were resolved by discussion or arbitration by a third reviewer (AS). We recalculated all the frequency estimates of any FA occurrence if adequate data were provided by authors by using minimal measured events rather than extrapolated ones. The 95% confidence intervals (95% CI) of our recalculations were computed by using the Wilson score method without continuity correction (15). We performed a random-effects meta-analysis for clinically and methodologically comparable studies to estimate the frequency of FA. We calculated the age-stratified pooled estimates for the age group 0–17 years (children) and 18 years and over (adults). We also present the pooled estimates stratified by geographical region in Europe. Statistical analysis was undertaken using STATA 11 (Stata Corp, College Station, Tx). See online supplement for further details.

Results
Study selection and characteristics
Figure 1 shows the PRISMA flowchart for our study selection and screening. Seventy-five papers (based
on 56 primary studies) were included in the narrative synthesis (16-89), and 30 studies were included in the meta-analysis (Figure 1). Further details are found in the online supplement (Table E1).

**Risk of bias assessment of studies**
The overall risk of bias grading of the studies indicated that almost all of the studies (54 of 56 studies) were graded as at ‘moderate’ risk of bias (Table E2).

**Frequency of FA**
Table 1 presents the summarized ranges of estimates for different age groups, by different assessment methods of FA, and includes the point prevalence for all FA assessment methods and life-time prevalence only for self-reported FA. Detailed results are shown in Tables E1 - E6.

**Self-reported FA**
The overall pooled point prevalence of self-reported FA was 5.9% (95% CI 5.7-6.1) (Figure 2). The pooled point prevalence among children was higher than among adults and highest in Northern Europe than in other regions (Figure 2). The overall pooled life-time prevalence of self-reported FA was 17.3% (95% CI 17.0-17.6), and this was similar in children and in adults and highest in Eastern Europe than other regions and lowest in Southern Europe. High prevalences were also reported in Western and Northern Europe (Figure E1). However, even after stratification by age and region, there was still significant heterogeneity between the studies (P < 0.001 for I²).

**FA by positive SPT or IgE to food allergens**
The overall point prevalence of positive specific-IgE to at least one food was 10.1% (95% CI 9.4-10.8) and higher among children than adults (Figure E2). The overall point prevalence of positive SPT to at least one food was 2.7% (95% CI 2.4-3.0) without differences between Northern and Southern Europe (Figure E3). After stratification by age and region, there was still significant heterogeneity between the studies (P < 0.001 for I²).

**FA defined by symptoms plus allergic sensitization and by clinical history or food challenge**
The overall pooled point prevalence of symptoms plus positive IgE to at least one food was 2.7% (95% CI 1.7-3.7), and slightly higher among children than...
### Table 1: Pooled point prevalence of self-reported FA stratified by age (Panel 1) and geographical region (Panel 2) in studies published in Europe between January 2000 and September 2012.

<table>
<thead>
<tr>
<th>Study</th>
<th>Percentage (95% CI)</th>
<th>Weight</th>
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<tbody>
<tr>
<td><strong>Children (0-17 years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffarelli (2011)</td>
<td>1.60 (0.90, 2.90)</td>
<td>2.00</td>
</tr>
<tr>
<td>Flokstra_de_Blok (2011)</td>
<td>2.10 (1.60, 2.80)</td>
<td>7.30</td>
</tr>
<tr>
<td>Kristinsdottir (2011)</td>
<td>5.50 (4.40, 6.90)</td>
<td>4.28</td>
</tr>
<tr>
<td>Kvenshagen (2009)</td>
<td>38.70 (34.60, 43.00)</td>
<td>1.64</td>
</tr>
<tr>
<td>Osterballe (2005)</td>
<td>11.90 (10.00, 14.10)</td>
<td>2.87</td>
</tr>
<tr>
<td>Penard_Morand (2006)</td>
<td>2.10 (1.80, 2.50)</td>
<td>21.32</td>
</tr>
<tr>
<td>Pereira (2005)</td>
<td>12.00 (10.50, 13.70)</td>
<td>4.89</td>
</tr>
<tr>
<td>Rance (2005)</td>
<td>4.70 (3.90, 5.50)</td>
<td>8.68</td>
</tr>
<tr>
<td>Sandin (2005)</td>
<td>22.90 (20.00, 26.00)</td>
<td>2.48</td>
</tr>
<tr>
<td>Steineke (2007)</td>
<td>5.00 (4.50, 5.40)</td>
<td>28.20</td>
</tr>
<tr>
<td>Venter (2008)</td>
<td>8.30 (6.70, 10.30)</td>
<td>2.85</td>
</tr>
<tr>
<td>Venter (2006)</td>
<td>11.80 (9.60, 14.20)</td>
<td>2.55</td>
</tr>
<tr>
<td><strong>Subtotal</strong> (I-squared = 99.3%, p = 0.000)</td>
<td>6.86 (6.58, 7.15)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Adults (&gt;= 18 years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falcao (2004)</td>
<td>5.20 (3.70, 7.10)</td>
<td>1.82</td>
</tr>
<tr>
<td>Kanny (2001)</td>
<td>3.50 (3.30, 3.70)</td>
<td>85.94</td>
</tr>
<tr>
<td>Marklund (2004)</td>
<td>18.70 (16.80, 20.80)</td>
<td>4.01</td>
</tr>
<tr>
<td>Mossakowska (2008)</td>
<td>3.30 (1.80, 6.00)</td>
<td>0.83</td>
</tr>
<tr>
<td>Osterballe (2009)</td>
<td>19.60 (17.00, 22.40)</td>
<td>2.33</td>
</tr>
<tr>
<td>Osterballe (2005)</td>
<td>14.10 (12.00, 16.50)</td>
<td>5.07</td>
</tr>
<tr>
<td><strong>Subtotal</strong> (I-squared = 99.1%, p = 0.000)</td>
<td>5.05 (4.82, 5.28)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Overall</strong> (I-squared = 99.2%, p = 0.000)</td>
<td>5.89 (5.71, 6.07)</td>
<td>.</td>
</tr>
</tbody>
</table>

**Panel 1**

**Panel 2**

<table>
<thead>
<tr>
<th>Study</th>
<th>Percentage (95% CI)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Western Europe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flokstra de Blok (2011)</td>
<td>2.10 (1.60, 2.80)</td>
<td>5.34</td>
</tr>
<tr>
<td>Kanny (2001)</td>
<td>3.50 (3.30, 3.70)</td>
<td>72.72</td>
</tr>
<tr>
<td>Penard-Morand (2005)</td>
<td>2.10 (1.80, 2.50)</td>
<td>15.60</td>
</tr>
<tr>
<td>Rance (2005)</td>
<td>4.70 (3.90, 5.50)</td>
<td>6.35</td>
</tr>
<tr>
<td><strong>Subtotal</strong> (I-squared = 98.0%, p = 0.000)</td>
<td>3.28 (3.12, 3.45)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Southern Europe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffarelli (2011)</td>
<td>1.60 (0.90, 2.90)</td>
<td>48.68</td>
</tr>
<tr>
<td>Falcao (2004)</td>
<td>5.20 (3.70, 7.10)</td>
<td>51.32</td>
</tr>
<tr>
<td><strong>Subtotal</strong> (I-squared = 94.2%, p = 0.000)</td>
<td>3.45 (2.45, 4.45)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Northern Europe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kristinsdottir (2011)</td>
<td>5.50 (4.40, 6.90)</td>
<td>9.37</td>
</tr>
<tr>
<td>Kvenshagen (2009)</td>
<td>38.70 (34.60, 43.00)</td>
<td>3.58</td>
</tr>
<tr>
<td>Ostblom (2008)</td>
<td>13.80 (12.50, 15.40)</td>
<td>24.01</td>
</tr>
<tr>
<td>Osterballe (2009)</td>
<td>19.60 (17.00, 22.40)</td>
<td>5.89</td>
</tr>
<tr>
<td>Osterballe (2005)</td>
<td>11.90 (10.00, 14.10)</td>
<td>6.28</td>
</tr>
<tr>
<td>Osterballe (2005)</td>
<td>14.10 (12.00, 16.50)</td>
<td>12.82</td>
</tr>
<tr>
<td>Pereira (2005)</td>
<td>12.00 (10.50, 13.70)</td>
<td>10.71</td>
</tr>
<tr>
<td>Sandin (2005)</td>
<td>22.90 (20.00, 26.00)</td>
<td>5.38</td>
</tr>
<tr>
<td>Venter (2008)</td>
<td>8.30 (6.70, 10.30)</td>
<td>6.23</td>
</tr>
<tr>
<td>Venter (2006)</td>
<td>11.80 (9.80, 14.20)</td>
<td>5.58</td>
</tr>
<tr>
<td><strong>Subtotal</strong> (I-squared = 97.8%, p = 0.000)</td>
<td>14.51 (13.88, 15.15)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Europe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steineke (2007)</td>
<td>5.00 (4.50, 5.40)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Subtotal</strong> (I-squared = .%, p = .)</td>
<td>5.00 (4.55, 5.45)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Eastern Europe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mossakowska (2008)</td>
<td>3.30 (1.80, 6.00)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Subtotal</strong> (I-squared = .%, p = .)</td>
<td>3.30 (1.20, 5.40)</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Overall</strong> (I-squared = 99.2%, p = 0.000)</td>
<td>5.89 (5.71, 6.07)</td>
<td>.</td>
</tr>
</tbody>
</table>
among adults (Figure 3). The overall pooled point prevalence of symptoms plus SPT positivity to at least one food allergen was 1.5% (95% CI 1.3-1.7) and this was only among children (Figure 4). Usually, the estimates for clinical history or OFC and clinical history or DBPCFC were close to each other, hence we report the point prevalence estimates for clinical history or DBPCFC. FA-defined clinical history refers to the cases confirmed by a convincing clinical judgment by a physician, without the use of any food challenge.
Figure 4  Pooled point prevalence of symptoms plus SPT positivity to at least one food allergen by age (PANEL 1) and geographical region (PANEL 2) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent the size of the study.
Epidemiology of food allergy in Europe: a review

This was mostly done for subjects who refused food challenge or could not undergo food challenge due to other reasons. The overall pooled point prevalence of clinical history or food challenge positivity was 2.6% (95% CI 2.1-3.1) and this was only among children from Northern Europe (Figure 5).

**Challenge-verified FA**

The overall pooled point prevalence of food challenge (OFC or DBPCFC) was 0.9% (95% CI 0.8-1.1) and was similar among children and adults, but highest in Western Europe, and being higher in Northern Europe than in Southern Europe (Table 1, Figure 6).

---

**Figure 5** Pooled point prevalence of clinical history of FA or food challenge (open food challenge or double-blinded placebo-controlled) by age (only studies among children available) (PANEL 1) and geographical region (only studies from Northern Europe available) (PANEL 2) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Figure 6 Pooled point prevalence of food challenge positivity (open food challenge or double-blinded placebo-controlled) by age (PANEL 1) and geographical region (PANEL 2) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Table 2  Time trends in the frequency of FA in Europe: estimates from studies published between 1 January 2000 and 30 September 2012

<table>
<thead>
<tr>
<th>Age(s) of subjects</th>
<th>Frequency of occurrence FA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUPTA et al. 2007(36), 2004(4), 2003(37), UK</td>
<td></td>
<td>The increasing trends hospital admissions for FA between the study years were statistically significant. These admission data do not include period accident and emergency departments for observation and are therefore likely to underestimate the actual incidence or prevalence.</td>
</tr>
<tr>
<td>Admissions rate for FA for all age groups</td>
<td>0.5</td>
<td>2.9</td>
</tr>
<tr>
<td>0-14 age group</td>
<td>1.6</td>
<td>11.8</td>
</tr>
<tr>
<td>15-44 age group</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>45+ age group</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>KOTZ et al. 2011(45), UK</td>
<td></td>
<td>All estimates were age- and- sex-standardized. During the study period, while the lifetime prevalence of peanut allergy doubled, the incidence rate of peanut allergy remained fairly stable. Sex-specific, age-specific, and SES-specific estimates are also reported in the paper.</td>
</tr>
<tr>
<td>All ages</td>
<td>2001</td>
<td>2002</td>
</tr>
<tr>
<td>Lifetime prevalence of doctor-diagnosed peanut allergy per 1000 patients Percentage (95% CI)</td>
<td>0.24 (0.22-0.26)</td>
<td>0.32 (0.30-0.34)</td>
</tr>
<tr>
<td>Incidence rate of doctor-diagnosed peanut allergy per 1000 person-years Percentage (95% CI)</td>
<td>0.06 (0.05-0.07)</td>
<td>0.08 (0.07-0.09)</td>
</tr>
<tr>
<td>Children 3-4 years</td>
<td>1993</td>
<td>1998-2000</td>
</tr>
<tr>
<td>Point prevalence of SPT positivity to peanut allergen Percentage (95% CI)</td>
<td>1.3% (0.6-1.8)</td>
<td>3.3% (2.4-4.4)</td>
</tr>
<tr>
<td>Point prevalence of clinician diagnosed peanut allergy (i.e. history plus sensitization plus OFC) Percentage (95% CI)</td>
<td>0.5% (0.2-1.1)</td>
<td>1.4% (0.9-2.2)</td>
</tr>
</tbody>
</table>

**Time-trends in the frequency of FA**

Only three studies have investigated the time-trends of FA in Europe (4, 36, 37, 45, 83) (Table 2). All these studies were from the UK and two were primarily hospital-based studies that employed only admissions data (4, 36, 37, 45), limiting the application of the findings to the general population, although the estimates were standardized to the local populations. Two focused on peanut allergy, while one considered any FA.

In the first study (45), while the incidence of doctor-diagnosed peanut allergy remained rather stable between 2001 and 2005, the life-time prevalence doubled during the study period. Using three different cohorts, Venter et al (2010) reported a significant increase in positive SPT to peanut allergen and clinical peanut allergy from 1993 to 1998-2000, but non-significantly decreased from 1998-2000 to 2004-2005 (83). Reviewing admissions rate for FA, Gupta and colleagues (4, 36, 37) observed an increased rate for all age groups between 1990 and 2004 (Table 2).
Risk and prognostic factors for FA

Risk factors for FA

Generally, the presence of other allergic diseases or allergic sensitization in the subjects, their parents, or siblings were strong risk factors for the development of FA (24-26, 34, 39, 57, 67-69, 72, 83-86). Increasing age appeared as a risk factor (34, 45, 68, 69). Male sex was associated with an increased risk in some studies (45, 68, 69) mainly among children, although other studies also reported no association (57). Higher socioeconomic status (45) or living in more affluent societies increased the risk (22). Caesarean section delivery and the use of antibiotics were not associated with FA (24-26, 52). In some studies, breastfeeding was not associated with the risk of FA (24-26, 57), although one study reported an increased risk (39). There was also an increased risk with the use of infant formula in one study (72). Other risk factors considered were inconsistently associated with FA across the studies.

Prognostic factors for FA

Of the various factors studied across the studies, no potential prognostic factor for the development of FA was reported, indicating that little data exist at present to indicate the prognosis of FA. Some studies have studied outgrowing (e.g. level of specific IgE) but our search strategy would not necessarily have picked up these studies.

Discussion

Statement of principal findings

The present systematic synthesis has provided estimates of the frequency of FA across different age groups and geographical regions in Europe. Almost all the studies received ‘moderate’ overall grading. Only a few of the studies were undertaken in Eastern and Southern Europe. The overall lifetime prevalence of self-reported food allergy was 17.3% (95% CI 17.0-17.6). Point prevalence for self-reported FA (5.9%), positive SPT to at least one food (2.7%), positive specific IgE (10.1%) and challenge-verified FA (0.9%) were lower. The highest prevalence was seen in North-western Europe and in children compared to adults. Low prevalence of self-reported and confirmed FA were found in Southern Europe, while sensitization was similar to other regions In Eastern Europe a high prevalence of self-reported FA was found with lacking data about sensitization or clinical reactivity. Although data on the time-trends of FA were weak, while the incidence of FA seemed to be stable over time, the prevalence appeared to be increasing. Finally, no consistent risk or prognostic factors for the development of FA were observed, although age, sex, and the presence of other allergic diseases seem potentially important.

Strengths and limitations

Rigorous steps were undertaken in the synthesis, including a comprehensive literature search that covered the major electronic databases; no language restriction; and rigorous screening and appraisal process undertaken. However, one of the limitations of this study is that due to the large amount of literature initially found, the review was restricted to studies published in Europe between 2000 and 2012 given the synthesis unpins the development of European guidelines. This is so far the first study to consider the frequency of FA by geographical regions and thus sets the pace for further consideration in future studies so as to clearly understand the spatial distribution of the disease. The highly significant heterogeneity in the pooled frequency estimates points to important differences among the studies in terms of differences in protocols such as food challenge and skin prick testing methodology. These differences indicate that caution should be exercised in interpreting the pooled results. The limited number of studies from Southern and Eastern Europe could also point to the fact that a majority of the studies published from these regions were done in local journals and in national languages which eventually are not indexed in the mainstream databases included in our study.

We were able to examine all possible methods that have been used to measure FA (e.g self-report, specific sensitization, food challenges and their various combinations)) and different measures of occurrence of FA (e.g point prevalence, lifetime prevalence incidence). We planned to additionally study case-fatality and resolution but their poor reporting made this impossible. Additionally most studies failed to make clear whether IgE or non-IgE phenotypes were being studied. Such uncertainty, in addition to the changing definition of FA, has so far also contributed to the difficulty in estimating the actual frequency of FA. Overall, the quality of studies included in the review was moderate. The methodological quality of future studies
Table 3  Summary of evidence on the risk/prognostic factors for FA in Europe: studies published between 1 January 2000 and 30 September 2012

<table>
<thead>
<tr>
<th>Reference, country</th>
<th>Outcomes</th>
<th>Risk/prognostic factors studied</th>
<th>Statistical analysis method</th>
<th>Results and comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Du Toit et al. 2008 (22), UK and Israel</td>
<td>OFC-verified peanut, sesame, tree nut, egg, and milk allergy</td>
<td>Country of residence (i.e. living in the United Kingdom as compared to living in Israel)</td>
<td>Mantel-Haenszel, Kaplan-Meier, log-rank test, multiple logistic regression</td>
<td>In both unadjusted and adjusted models: ↑living in the United Kingdom (compared to living in Israel) associated with peanut, sesame, tree nut, egg, and milk allergy. Early consumption of peanuts in infancy was associated with lower risk of peanut allergy, but estimates for this were not reported in the paper.</td>
</tr>
<tr>
<td>Eggesbø et al. 2001a, 2001b and 2003 (24-26), Norway</td>
<td>History and OFC/DBPCFC-confirmed</td>
<td>Cesarean section, maternal antibiotics, child antibiotics, breast feeding, maternal allergy, older siblings</td>
<td>Pearson Chi-square test, logistic regression,</td>
<td>↑ Maternal allergy, → cesarean delivery, → maternal antibiotics, → child antibiotics, → breast feeding, → older siblings</td>
</tr>
<tr>
<td>Fox et al. 2009 (32), UK</td>
<td>SPT or sIgE positivity or DBPCFC</td>
<td>Environmental (household) peanut consumption, maternal peanut consumption during pregnancy and lactation, infant peanut consumption</td>
<td>Wilcoxon rank-sum test, multiple logistic regression,</td>
<td>In adjusted models: ↑higher household peanut consumption; →maternal peanut consumption during pregnancy; →maternal peanut consumption during lactation.</td>
</tr>
<tr>
<td>Gelincik et al. 2008 (34), Turkey</td>
<td>DBPCFC-verified FA</td>
<td>Age, familial atopy, household pets, nasal allergy, itching dermatitis/urticaria, doctor-diagnosed asthma, smoking</td>
<td>Pearson’s Chi-square test, multiple logistic regression</td>
<td>In adjusted models: ↑age &lt; 40 years; ↑familial atopy; ↑household pets; ↑nasal allergy; ↑itching dermatitis/urticaria; ↑doctor-diagnosed asthma. Only the factors that were significant at the unadjusted level were included in the adjusted models.</td>
</tr>
<tr>
<td>Hourihane et al. 2007 (39), UK</td>
<td>DBPCFC-verified peanut allergy</td>
<td>Breastfeeding, history of eczema and allergic rhinitis</td>
<td>Multiple logistic regression</td>
<td>DBPCFC-verified peanut allergy: ↑breastfeeding; ↑history of eczema. All these results were from adjusted models.</td>
</tr>
<tr>
<td>Kotz et al. 2011 (45), UK</td>
<td>Physician-diagnosed peanut allergy</td>
<td>Sex, age, socioeconomic deprivation</td>
<td>Pearson’s Chi-square test</td>
<td>Incidence: ↑male sex; ↑0-4 years old; ↑being in the most affluent group</td>
</tr>
<tr>
<td>Kvenshagen et al. 2009 (52), Norway</td>
<td>Clinician diagnosed allergy to any food</td>
<td>Caesarean section, use of antibiotics</td>
<td>Logistic regression</td>
<td>Prevalence: ↑5-9 years old; being in the most affluent group</td>
</tr>
</tbody>
</table>

Only frequencies and p-values were reported; no modeling strategies were employed in the analysis.
<table>
<thead>
<tr>
<th>Reference, country</th>
<th>Outcomes</th>
<th>Risk/prognostic factors studied</th>
<th>Statistical analysis method</th>
<th>Results and comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicolaou et al. 2010 (57), UK</td>
<td>History plus OFC/DBPCFC-verified peanut allergy</td>
<td>Sex, breastfeeding, maternal allergy, paternal allergy, current asthma/wheeze, current hay fever, current eczema, other known food allergies, median serum sIgE, peanut SPT &gt; 8 mm</td>
<td>Pearson’s Chi-square test</td>
<td>→Male sex; →breastfed; →maternal allergic disease; →paternal allergic disease; ↑current asthma/wheeze; ↑current hay fever; ↑current eczema; ↑other known food allergies; ↑median serum sIgE to peanut; ↓median serum sIgE to grass; ↑median serum sIgE to peanut; ↑peanut SP weal &gt; 8 mm. Only frequencies and p-values were reported; no modeling strategies were employed in the analysis.</td>
</tr>
<tr>
<td>Pereira et al. 2005 (67), UK</td>
<td>Self-reported FA</td>
<td>Atopic status</td>
<td>Binary logistic regression</td>
<td>In unadjusted model: ↑age ≥ 1 years (compared to age 1 year); ↑male sex; →one or more siblings. In adjusted model: ↑either one or both parents having FA symptoms; ↑increased number of parental FA symptoms. The factors studied in the unadjusted model were not adjusted for and vice versa for factors studied in the adjusted model.</td>
</tr>
<tr>
<td>Pyrhönen et al. 2011 and 2009 (68, 69), Finland</td>
<td>Physician diagnosed FA and OFC-verified FA</td>
<td>Age, sex, no. of siblings, parental allergy (FA symptoms, animal allergy, hay fever, atopic rash, allergic asthma, any allergy, positivity to milk allergy; egg allergy; essential foods allergy)</td>
<td>Kaplan-Meier analyses and multiple Cox proportional regression</td>
<td></td>
</tr>
<tr>
<td>Roberts et al. 2005 (72) and Lack et al. 2003 (73), UK</td>
<td>DBPCFC-verified peanut allergy</td>
<td>SES, environmental tobacco smoke, maternal history of asthma, eczema, hay fever, other specific allergies, atopy; maternal intake of soybean meat, nuts during pregnancy; infant’s breastfeeding status, use of soy milk or soy formula in 1st 2 yrs, rashes in 1st 6 months</td>
<td>Multiple logistic regression</td>
<td>Adjusted models: ↑consumption or formula during infancy; ↑trash over joints and in skin creases; ↑Oozing, crusted rash</td>
</tr>
<tr>
<td>Venter et al. 2010 (83), UK</td>
<td>Physician diagnosed and OFC/DBPCFC-verified peanut allergy</td>
<td>Having allergic diseases (wheeze, eczema) and increased SPT antibodies to food and inhalant allergens (house dust mite, grass, cat, milk, egg, wheat, and sesame)</td>
<td>Pearson’s Chi-square test and binary logistic regression</td>
<td>Unadjusted models: ↑ever wheeze; ↑wheeze in past 12 months; ↑ever physician-diagnosed eczema; ↑sensitization to house dust mite, grass, cat, milk, egg, wheat, and sesame. No adjusted models were computed for the estimates.</td>
</tr>
<tr>
<td>Venter et al. 2008 (84); Dean et al. 2007 (85); Venter et al. 2006 (86, 87), UK</td>
<td>Physician diagnosed and OFC/DBPCFC-verified FA</td>
<td>Sex, sibship, maternal and family history of atopy</td>
<td>Fisher’s exact test, calculation of relative risk based on contingency tables</td>
<td>Estimates of associations between the risk factors and the endpoints not reported in the paper.</td>
</tr>
</tbody>
</table>

† Indicates a statistically significant increased risk (risk factor);
↓ Indicates a statistically significant decreased risk (protective factor);
→ Indicates no statistically significant association between the factor of interest and FA endpoint.

DBPCFC: double-blind, placebo-controlled food challenge; OFC: oral/open food challenge; sIgE: specific immunoglobulin E test; SPT: skin prick test for sensitization to specific food allergens.
needs to be improved, for example the gold standard DBPCFC should be used. However, the OFC is more often applied as DBPCFC is not yet common practice in many settings. Additionally, using DBPCFC can be problematic because many symptomatic individuals are not challenged due to co-existing disease, lack of validated and blinded challenge materials or refusal, which could result into an underestimation of the real frequency of FA. However, the comparable DBPCFC estimates across different age groups indicate that the DBPCFC estimates obtained in this study are likely robust. Overall, using estimates where subjects with convincing clinical history and those with positive food challenge were combined as history or FC may represent the best estimates.

Due to wide variations in the definition of FA based on IgE or SPT sensitization to food allergens across the studies, comparison of estimates from studies that used these methods is also difficult. For instance, the values used for defining both positive IgE and SPT were inconsistent across a number of studies. Also, the number of specific foods tested was inconsistent across studies. Data indicates that the most common sensitized allergens are scantly represented in available commercial mixes, thus the observed frequency of FA may be an underestimation (18). Allergies to very common inhalant allergies, such as grass pollen, house dust mites, and cockroaches, may lead to non-clinically relevant SPT- or IgE-positivity to cereals, peanut, and shrimp (90-92). This may inhibit valid estimation of the frequency of FA based on sensitization to specific food allergens. Finally, the diagnostic methods used to assess FA sensitization varied widely across studies, which may also reflect geographic variability in application of diagnostic tools for defining FA sensitization.

**Comparison of our findings with previous studies**

We identified three previous systematic reviews that investigated the frequency of FA (16, 74, 89). Zuidmeer and colleagues focused only on the prevalence of plant food allergies and only searched the MEDLINE database, reporting estimates generally lower than our estimates (89). We searched four databases and had no restriction to the type of foods examined. The latest of the three systematic reviews (16) reported frequency of FA based on the estimates reported in a previous review (74), in which the prevalence of self-reported FA was around 12% in children and around 13% in adults (74). These compare to 6.9% and 5.1% respectively in our study. That review also reported a lower range of prevalence for positive specific-IgE to at least one food (4-6%) but a higher range of positive SPT to at least one food (7-17%). The overall pooled estimate of FA by food challenge was above 2% in that study (74), twice our estimate (0.9%). The previous systematic review excluded primary studies that examined fruits, vegetables, seeds, nuts, cereals, and meats, and included primary studies both from Europe and beyond. These may partly explain the differences in estimates found between our review and the previous ones. Only one of the previous studies examined the time-trends in the frequency of FA and concluded that it is unclear if the prevalence is increasing and that the observed increase over time could be attributed to increased awareness and improved pattern of reporting and diagnosis rather than a true increase (14). We did not identify any previous systematic review that has investigated the risk or prognostic factors for FA.

**Conclusions**

The present evidence indicates that the lifetime and point prevalence of self-reported FA in Europe are around 17% and 6%, respectively. The point prevalence of food challenge-confirmed FA is under 1%. The frequency of FA is higher among children than among adults and highest in North-western Europe than in other regions, while Southern Europe seems to have the lowest prevalence. Caution is required due to the heterogeneity among the studies suggesting important methodological and diagnostic differences within and across geographic regions of Europe. Whilst the incidence of FA seems stable over time, the prevalence may be increasing, possibly reflecting changes in diagnostic practices or longer time to resolution. The risk or prognostic factors for the development of FA are inconsistent, although sex, age, country of residence, the presence of other allergic diseases, and familial history of allergy may be important. Clearly, there is need to improve this evidence base in order to validly estimate the putative frequency of food allergy. Future studies need to be rigorously designed using standardized methodology including DBPCFC to limit potential sources of bias that could weaken the estimates of food allergy and more high-quality studies are needed from Eastern and Southern Europe (93, 94).
Acknowledgements

We would like to acknowledge the support of EAACI and the EAACI Food Allergy and Anaphylaxis Guidelines Group in developing this systematic review. We would also like to thank the EAACI Executive Committee for their helpful comments and suggestions.

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EAACI

Contributorship

AS, AM and GR conceived this review. It was undertaken by BN and LH, with the support of SSP. BN, LH, GR and AS led the drafting of the manuscript and all authors critically commented on drafts of the manuscript.

Conflicts of interest

None known

References


83. Venter C, Arshad SH, Grundy J, Pereira B, Bernie Clayton C,
Voigt K et al. Time trends in the prevalence of peanut allergy: Three cohorts of children from the same geographical location in the UK. Allergy 2010;65:103-108.


1.2 PREVALENCE OF COMMON FOOD ALLERGIES IN EUROPE
SYSTEMATIC REVIEW AND META-ANALYSIS

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9 Department of Medicine, Harvard Medical School, Boston, MA, USA
**Background:** Allergy to cow’s milk, egg, wheat, soy, peanut, tree nut, fish, and shellfish constitute the majority of food allergy reactions, but reliable estimates of their prevalence are lacking. This systematic review aimed to provide up-to-date estimates of their prevalence in Europe.

**Methods:** Studies published in Europe from January 1, 2000 to September 30, 2012 were identified from searches of four electronic databases. Two independent reviewers appraised the studies and extracted the estimates of interest. Data were pooled using random-effects meta-analyses.

**Results:** Fifty studies were included in a narrative synthesis and 42 studies in the meta-analyses. Although there were significant heterogeneity between the studies, the overall pooled estimates for all age groups of self-reported lifetime prevalence of allergy to cow’s milk was 6.0% (95% Confidence Interval: 5.7-6.4), egg 2.5% (2.3-2.7), wheat 3.6% (3.0-4.2), peanut 0.4% (0.3-0.6), tree nut 1.3% (1.2-1.5), fish 2.2% (1.8-2.5), and shellfish 1.3% (0.9-1.7). The prevalence of food-challenge defined cow’s milk allergy was 0.6% (0.5-0.8), egg 0.2% (0.2-0.3), wheat 0.1% (0.01-0.2), soy 0.3% (0.1-0.4), peanut 0.2% (0.2-0.3), tree nut 0.5% (0.08-0.8), fish 0.1% (0.02-0.2), and shellfish 0.1% (0.06-0.3). Allergy to cow’s milk and egg was more common among younger children, while peanut, tree nut, fish, and shellfish were more common among the older ones. There were insufficient data to compare the estimates of soy and wheat allergy between the age groups. Allergy to most foods, except soy and peanut, appeared to be more common in Northern Europe. The lifetime self-reported prevalence of allergy to common foods in Europe ranged from 0.1-6.0%. The heterogeneity between studies was high and participation rates varied across studies reaching as low as less than 20% in some studies.

**Conclusions:** The current study has provided the most comprehensive and up-to-date estimates so far of the eight most common food allergies across different age groups and regions in Europe. Standardizing the methods of assessment of food allergies and initiating strategies to increase participation will advance this evidence base.

**BACKGROUND**

The majority of allergic reactions to foods, particularly in children, are suggested to be caused primarily by eight foods, namely cow’s milk, egg, wheat, soy, peanut, tree nut, fish, and shellfish (1), although there is no sufficient evidence to support this in Europe. Although it has been suggested that the prevalence of adverse reactions to these foods are increasing and constituting major public health problems, including increasing hospital utilization, increasing associated medical costs, and increased burden of care on immediate families (1-8), reliable estimates of their prevalence in Europe are lacking.

As part of the efforts of the European Academy of Allergy and Clinical Immunology (EAACI) to develop guidelines (EAACI Guidelines for Food Allergy and Anaphylaxis) for the management and prevention of food allergy and anaphylaxis, we undertook a systematic review to appraise the evidence base on the epidemiology of food allergy, its prevention, diagnosis and clinical management, and impact on quality of life, which will be used to inform the clinical recommendations. In our first report of the findings of this synthesis, we presented estimates of the prevalence, time-trends, and risk and prognostic factors for allergy to any food (Chapter 1.1) (9). In the present analysis, we present the estimates of the prevalence of the above-named eight most common food allergies in Europe.

**METHODS**

**Study protocol, search strategy, and study selection**

The detailed methodological approach employed in this systematic review has been presented in our first report (9). Briefly, we developed a protocol in advance on the review processes, including the search strategies, inclusion and exclusion criteria, methods of analyses and syntheses, and choice of risk of bias tools for assessing study quality. The protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) at http://www.crd.york.ac.uk/prospero/ (registration number CRD42013003704) and has been published (10). We implemented a highly sensitive search strategy in four electronic databases (OVID MEDLINE, OVID EMBASE, CINAHL, and ISI Web of Science), which was devised on OVID MEDLINE and then adapted to the other databases. Experts active in the field commented on the search strategy and the list of included studies. Additional references were located by searching the references cited in the identified studies. Unpublished work and research in progress were searched through discussion with experts in the field. We made no restrictions based on language; and literature in languages other than English were, where possible, translated.

In terms of study design, we included systematic reviews and meta-analyses, cohort studies, case-control studies, cross-sectional studies, and routine healthcare studies, but excluded review and discussion papers, non-research letters and editorials, case studies and case series, animal studies, and all randomized controlled trials. As our initial search (including studies published worldwide between January 1990 and September 2012) retrieved large quantities of articles, we restricted the studies to those published in Europe between January 1, 2000 and September 30, 2012. After initial screening of the retrieved studies by two independent reviewers, the abstracts and full text copies of potentially relevant studies were obtained and their eligibility for inclusion was independently assessed by two reviewers (BN and LH). Any discrepancies were resolved by consensus and, if necessary, a third reviewer (AS) arbitrated.

**Outcomes**

The food allergy outcomes assessed in this review included cow’s milk, egg, wheat, soy, peanut, tree nut, fish, and shellfish. We included eligible studies that have assessed these outcomes based on self-report (i.e., participants or their parents reported that they have any of the outcomes or not), skin prick test (SPT) positivity, specific immunoglobulin E (IgE) positivity, open food challenge (OFC)/double blind placebo-controlled food challenge (DBPCFC)-positivity, OFC/DBPCFC-positivity or convincing clinical history (i.e., outcomes confirmed by a convincing clinical judgment by a physician without food challenge).

**Assessment of risk of bias**

We assessed the risk of bias in the studies by using an adapted and modified relevant version of the Critical Appraisal Skills Programme (CASP) quality assessment tool (http://www.casp-uk.net/). As we described in our previous report, each component of the studies (i.e., the appropriateness of the study design for the
Prevalence of common food allergies in Europe

Research question, the risk of selection bias, exposure measurement, and outcome assessment) was graded and an overall grading was calculated from grading for the different study components (9). Two reviewers (BN and LH) independently assessed the risk of bias in the studies and any discrepancies were resolved by consensus and, if necessary, a third reviewer (AS) arbitrated.

Analysis
Using a customized data extraction form, we recalculated all the frequency estimates of food allergy occurrence if adequate data were provided by authors using minimal measured events rather than extrapolated estimates. If any discrepancies were observed between our recalculated estimates and those of the authors, we preferentially reported our recalculated estimates. If inadequate data were given to enable recalculation, we reported the estimates provided by the authors. Where needed and possible, we contacted authors of primary studies for clarifications. To adjudge the precision of the prevalence estimates presented in the studies, we extracted the 95% confidence intervals (95% CI) of the estimates from the studies and where we undertook the recalculation of the estimates, the 95% CI were computed by using the Wilson score method without continuity correction (11). All the different reports from the same primary study were reported together. We performed a random-effects meta-analysis for clinically and methodologically comparable studies (comparable particularly with regards to the type of endpoint measure [point or lifetime prevalence] and assessment method [self-report, SPT, IgE, FC] reported in the studies), excluding systematic reviews, to estimate the prevalence of each specific food allergy based on the different assessment methods.

The pooled estimates were stratified by age (≤ 1 year, 2-5 years, 6-17 years, ≥18 years) and geographical region of Europe (i.e., East, West, South, and North). A study with overlap between the age groups was included in an age group if the age distribution was skewed to that age group. For cohort studies that gave frequency estimates at different ages for the same individuals, we used the estimates for the highest age within each age strata in computing the pooled estimates. For studies reporting more than one tree nut, each tree nut was separately included in the pooled estimates. The heterogeneity of the estimates was computed both for the stratified analysis and for all the groups combined.

Statistical analyses were undertaken using STATA 11 (Stata Corp, College Station, Tx).

RESULTS
Study selection and characteristics
Our initial database searches identified 4053 articles and an additional 11 studies through hand searches and expert suggestions, giving a total of 4064 articles that were screened. After removal of duplicates and taken into account the pre-defined exclusions based on titles and abstracts, the full texts of 109 articles were examined in more detail. For the current report, of the 109 articles, 26 were excluded for not being population-based, 8 for not studying any of the eight specific food allergies of interest, and 10 excluded for being unable to be translated into English, leaving us with 65 papers (based on 50 primary studies) that were finally included in the narrative synthesis (12-80), and 42 studies included in at least one meta-analysis. Of the 50 primary studies reviewed, 27 were cross-sectional studies, 17 cohort studies, three systematic reviews, and three case-control studies. A majority of the studies (n = 37) were undertaken exclusively in children, usually those less than 18 years of age. The majority of the studies were from Northern and Western Europe.

Of the 50 primary studies, 42 examined cow’s milk allergy, 44 egg allergy, 25 wheat allergy, 17 soy allergy, 36 peanut allergy, 26 tree nut allergy, 31 fish allergy, and 15 shellfish allergy (Table 1 and Tables E1 & E2). Of the 42 studies included in the meta-analysis, 35 were included for cow’s milk allergy, 33 for egg allergy, 17 for wheat allergy, 11 for soy allergy, 29 for peanut allergy, 20 for tree nut allergy, 19 for fish allergy, and 9 for shellfish allergy. For each specific food allergy, all of the assessment methods (self-report, SPT sensitization, specific IgE sensitization, and food challenge) were employed to measure food allergy, although self-report was most commonly used. Some studies combined symptoms plus either SPT or IgE sensitization to measure food allergy, while few studies used food challenge or convincing clinical history (Table 1). Table 1 presents the characteristics of the studies included in the review. The participation rate across studies varied widely, ranging between as low as 17.3% to 99.5%, while in several studies the participation rate was not reported.
Table 1  Summary of the characteristics of studies in the review: studies published 1 January 2000 – 30 September 2012

<table>
<thead>
<tr>
<th>Reference, country¹</th>
<th>Study design</th>
<th>Number invited/eligible participants</th>
<th>Participation rate N (%)</th>
<th>Age of subjects</th>
<th>Method of outcome assessment</th>
<th>Measure(s) of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burney et al. 2010 (12); Woods et al. 2001 (13), Europe, USA, Australia, New Zealand</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>4522</td>
<td>20-44 years old</td>
<td>Self-reported, sIgE</td>
<td>Point and life-time prevalence</td>
</tr>
<tr>
<td>Caffarelli et al. 2011 (14), Italy</td>
<td>Cross-sectional study</td>
<td>900</td>
<td>625 (69.4)</td>
<td>5-14 years old</td>
<td>Self-reported</td>
<td>Point and life-time prevalence</td>
</tr>
<tr>
<td>Chafen et al. 2010 (15), World-wide</td>
<td>Systematic review</td>
<td>1216 studies</td>
<td>72 studies included</td>
<td>All age groups</td>
<td>Self-reported, physician-diagnosis, SPT, sIgE, OFC, DBPCFC</td>
<td>Point, period, life-time prevalence; cumulative incidence, incidence rate</td>
</tr>
<tr>
<td>Du Toit et al. 2008 (16), UK and Israel</td>
<td>Cross-sectional study</td>
<td>10786</td>
<td>8826 (81.8)</td>
<td>4-18 years old</td>
<td>Self-reported, clinical history, OFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Dubakiene et al. 2012 (17), Lithuania</td>
<td>Cohort study</td>
<td>Not indicated</td>
<td>1558</td>
<td>6-12 months old</td>
<td>Self-reported, SPT, sIgE, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Eggesbø et al. 2003, 2001a and 2001b (18-20), Norway</td>
<td>Cohort study</td>
<td>4973</td>
<td>3754 (75.5)</td>
<td>2.5 years old</td>
<td>Self-reported, physician-diagnosis, SPT, sIgE, OFC, DBPCFC</td>
<td>Point prevalence, cumulative incidence</td>
</tr>
<tr>
<td>Eller et al. 2009 (21), Kjaer et al. 2008 (22), Johnke et al. 2006 (23), Denmark</td>
<td>Cohort study</td>
<td>1095</td>
<td>562 (51.3)</td>
<td>6 years old</td>
<td>Self-reported, SPT, sIgE, OFC, DBPCFC</td>
<td>Point prevalence, cumulative incidence</td>
</tr>
<tr>
<td>Falcaõ et al. 2004 (24), Portugal</td>
<td>Cross-sectional study</td>
<td>1565</td>
<td>659 (42.1)</td>
<td>&gt;39 years old</td>
<td>Self-reported</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Fox et al. 2009 (26), UK</td>
<td>Case-control study</td>
<td>Not indicated</td>
<td>133 cases, 310 controls</td>
<td>&lt; 4 years</td>
<td>SPT, sIgE, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Frongia et al. 2005 (27), Italy</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>2284</td>
<td>11-20 years old</td>
<td>Self-reported</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Gelincik et al. 2008 (28), Turkey</td>
<td>Cross-sectional study</td>
<td>17064</td>
<td>11816 (69.2)</td>
<td>≥ 18 years old</td>
<td>Self-reported, SPT, sIgE, DBPCFC</td>
<td>Point and life-time prevalence</td>
</tr>
<tr>
<td>Grundy et al. 2002 (29), UK</td>
<td>Cohort study</td>
<td>2858</td>
<td>1273 (44.5)</td>
<td>3-4 years old</td>
<td>Self-report, SPT, OFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Hourihane et al. 2007 (31), UK</td>
<td>Cross-sectional study</td>
<td>5072</td>
<td>1125 (22.2)</td>
<td>4-5 years old</td>
<td>SPT, sIgE, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Høst et al. 2002 (30), Denmark</td>
<td>Cohort study</td>
<td>1758</td>
<td>1749 (99.5)</td>
<td>15 years old</td>
<td>SPT, sIgE, OFC, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Isolauri et al. 2004 (32), Finland</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>400</td>
<td>7, 27, 47, 67 years</td>
<td>Self-reported, sIgE</td>
<td>Lifetime prevalence and point prevalence</td>
</tr>
<tr>
<td>Johansson et al. 2005 (33), Sweden and Norway</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>Sweden 1002; Norway 500</td>
<td>Adults</td>
<td>sIgE</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Julge et al. 2001 (34), Vasar et al. 2000 (35), Estonia</td>
<td>Cohort study</td>
<td>455</td>
<td>298 (65.5)</td>
<td>5 years</td>
<td>SPT, sIgE</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Krause et al. 2002 (37), Greenland</td>
<td>Cross-sectional study</td>
<td>1213</td>
<td>1 068 (88.1)</td>
<td>5-18 years old</td>
<td>sIgE</td>
<td>Point prevalence</td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>Reference, country(^1)</th>
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<th>Number invited/eligible participants</th>
<th>Participation rate N (%)</th>
<th>Age of subjects</th>
<th>Method of outcome assessment</th>
<th>Measure(s) of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kristinsdottir et al. 2011 (38), Iceland</td>
<td>Cohort study</td>
<td>Not indicated</td>
<td>1341</td>
<td>1 year old</td>
<td>Self-reported, SPT, specific sIgE, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Kucosmanoglu et al. 2008 (39), Turkey</td>
<td>Cross-sectional study</td>
<td>1415</td>
<td>1015 (71.7)</td>
<td>8-18 months</td>
<td>SPT</td>
<td>Point prevalence</td>
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<tr>
<td>Kurulaaratchy et al. 2005 (40), Arshad et al. 2001 (41), Tariq et al. 2000 (42), UK</td>
<td>Cohort study</td>
<td>1536</td>
<td>1456 (94.8)</td>
<td>4 years old</td>
<td>SPT</td>
<td>Point prevalence, cumulative incidence</td>
</tr>
<tr>
<td>Kvenshagen et al. 2009 (43), Norway</td>
<td>Cohort study</td>
<td>Not indicated</td>
<td>609</td>
<td>2 years old</td>
<td>Self-reported, SPT, sIgE, OFC, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Majkowska-Wojciechowska et al. 2009 (44), Poland</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>2148</td>
<td>7-10 years old</td>
<td>Self-reported</td>
<td>Life-time prevalence</td>
</tr>
<tr>
<td>Marklund et al. 2004 (45), Sweden</td>
<td>Cross-sectional study</td>
<td>2064</td>
<td>1488 (72.1)</td>
<td>13-21 years old</td>
<td>Self-reported</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Matricardi et al. 2007 (46), Germany</td>
<td>Cross-sectional study</td>
<td>7609</td>
<td>1314 (17.3)</td>
<td>2-10 years old</td>
<td>sIgE</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Mossakowska et al. 2008 (47) Poland</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>301</td>
<td>&gt;100 years old</td>
<td>Self-reported</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Nicolaou et al. 2010 (48), UK</td>
<td>Cohort study</td>
<td>1085</td>
<td>1029 (94.8)</td>
<td>8 years old</td>
<td>Self-reported, SPT, sIgE, OFC, DBPCFC</td>
<td>Point and lifetime prevalence</td>
</tr>
<tr>
<td>Niggemann et al. 2011 (49), Germany</td>
<td>Cross-sectional study</td>
<td>26787</td>
<td>13100 (48.9)</td>
<td>0-17 years old</td>
<td>sIgE</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Orhan et al. 2009 (50), Turkey</td>
<td>Cross-sectional study</td>
<td>3500</td>
<td>2739 (78.2)</td>
<td>6-9 years old</td>
<td>Self-reported, SPT, OFC, DBPCFC</td>
<td>Life-time and point prevalence</td>
</tr>
<tr>
<td>Östblom et al. 2008a, 2008b, 2008c (51-53) and Almqvist et al. 2005 (54), Sweden</td>
<td>Cohort study</td>
<td>Not indicated</td>
<td>4089</td>
<td>4-8 years old</td>
<td>Self-reported, sIgE</td>
<td>Point and period prevalence</td>
</tr>
<tr>
<td>Osterballe et al. 2009 (55), Denmark</td>
<td>Cross-sectional study</td>
<td>1094</td>
<td>843 (77.1)</td>
<td>Mean age 22 years</td>
<td>Self-reported, SPT, OFC, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Osterballe et al. 2005 (56), Denmark</td>
<td>Cohort study</td>
<td>Not indicated</td>
<td>1834</td>
<td>Children and adults</td>
<td>Self-reported, physician diagnosis, SPT, sIgE, OFC, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Penard-Morand et al. 2005 (57), France</td>
<td>Cross-sectional study</td>
<td>9615</td>
<td>7781 (80.9)</td>
<td>9-11 years old</td>
<td>Self-reported, SPT</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Pereira et al. 2005 (58), UK</td>
<td>Cross-sectional study</td>
<td>3144</td>
<td>1532 (48.7)</td>
<td>11 and 15 year old</td>
<td>Self-reported, physician diagnosis, SPT, OFC, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Pyhönen et al. 2011 and 2009 (59-60), Finland</td>
<td>Cohort study</td>
<td>5973</td>
<td>3899 (65.3)</td>
<td>0-4 years old</td>
<td>Self-reported, physician-diagnosis, SPT, sIgE, OFC</td>
<td>Life-time prevalence, cumulative incidence</td>
</tr>
<tr>
<td>Pyziak and Kamer 2011 (61), Poland</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>83</td>
<td>6-17 years old</td>
<td>Self-reported, sIgE, SPT, OFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Rance et al. 2005 (62), France</td>
<td>Cross-sectional study</td>
<td>3500</td>
<td>2716 (77.6)</td>
<td>Mean age 8.9 years</td>
<td>Self-reported</td>
<td>Point and lifetime prevalence</td>
</tr>
</tbody>
</table>
### Table 1 (continued)

<table>
<thead>
<tr>
<th>Reference, country(^1)</th>
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<th>Participation rate N (%)</th>
<th>Age of subjects</th>
<th>Method of outcome assessment</th>
<th>Measure(s) of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roberts et al. 2005 (63) and Lack et al. 2003 (64), UK</td>
<td>Cohort study</td>
<td>13971</td>
<td>12090 (86.5)</td>
<td>0-7 years</td>
<td>Self-reported, SPT, DBPCFC</td>
<td>Point Prevalence</td>
</tr>
<tr>
<td>Rona et al. 2007 (65), World-wide</td>
<td>Systematic review</td>
<td>Not indicated</td>
<td>Number of studies included in review not indicated</td>
<td>All age groups</td>
<td>Self-reported, physician-diagnosis, SPT, sIgE, OFC, DBPCFC</td>
<td>Point, period, lifetime prevalence, cumulative incidence, incidence rate</td>
</tr>
<tr>
<td>Ronchetti et al. 2008 (66), Italy</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>380</td>
<td>9 and 13 years old</td>
<td>SPT</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Sandin et al. 2005 (67), Sweden and Estonia</td>
<td>Case-control study</td>
<td>All 985 Sweden 645 Estonia 340</td>
<td>All 770 (78.2) Sweden 483 (74.9) Estonia 287 (84.4)</td>
<td>10-11 years old</td>
<td>Self-report, sIgE</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Schnabel et al. 2010 (68), Germany</td>
<td>Cohort study</td>
<td>3097</td>
<td>1082 (34.9)</td>
<td>6 years old</td>
<td>Self-reported, sIgE</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Schäfer et al. 2001 (69), Germany</td>
<td>Nested case-control study</td>
<td>2539</td>
<td>1537 (60.5)</td>
<td>25-74</td>
<td>Self-reported, SPT</td>
<td>Point prevalence, lifetime prevalence</td>
</tr>
<tr>
<td>Soost et al. 2009 (70) and Zuberbier et al. 2004 (72), Roehr et al. 2004 (71), Germany</td>
<td>Cross-sectional study</td>
<td>13300</td>
<td>All: 4093 (30.8) Age 0-17 years: 739 Age 18-79 years: 3227</td>
<td>0-79 years old</td>
<td>Self-reported, physician diagnosis, SPT, sIgE, OFC, SBPCFC, DBPCFC</td>
<td>Point and life-time prevalence</td>
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<tr>
<td>Steinke et al. 2007 (73), Europe</td>
<td>Cross-sectional study</td>
<td>Not indicated</td>
<td>40426</td>
<td>&lt; 18 years</td>
<td>Self-reported</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Venter et al. 2010 (74), UK</td>
<td>Cohort study</td>
<td>5283</td>
<td>3382 (64.0)</td>
<td>3-4 years old</td>
<td>Physician diagnosis, SPT, sIgE, OFC, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>Venter al 2008 (75); Dean et al. 2007 (76); Venter et al. 2006 (77), UK</td>
<td>Cohort study</td>
<td>1096</td>
<td>969 (88.4)</td>
<td>3 years old</td>
<td>Self-report, SPT, OFC, DBPCFC</td>
<td>Point and period prevalence, cumulative incidence</td>
</tr>
<tr>
<td>Venter et al. 2006 (78), UK</td>
<td>Cross-sectional study</td>
<td>1440</td>
<td>798 (55.4)</td>
<td>6 years old</td>
<td>Self-report, SPT, OFC, DBPCFC</td>
<td>Point prevalence</td>
</tr>
<tr>
<td>von Hertzen et al. 2006 (79), Finland and Russia</td>
<td>Cross-sectional study</td>
<td>Finland: children 546 mothers 546 Finland: Children 413 (75.6) Mothers 409 (74.9)</td>
<td>7-16 years children</td>
<td>SPT</td>
<td>Point prevalence</td>
<td></td>
</tr>
<tr>
<td>Zuidmeer et al. 2008 (80), World-wide</td>
<td>Systematic review</td>
<td>396 studies</td>
<td>33 studies included</td>
<td>All age groups</td>
<td>Self-reported, physician-diagnosis, SPT, sIgE, OFC, DBPCFC</td>
<td>Point, period, and life-time prevalence</td>
</tr>
</tbody>
</table>

\(^1\) All studies were graded as at moderate overall risk of bias, except Caffarelli et al. (14) which was graded strong.

CI = confidence interval; DBPCFC = double blind placebo-controlled food challenge; OFC = oral food challenge; sIgE = specific immunoglobulin E; SPT = skin prick test; SR = self-reported
Assessment of risk of bias
We presented details of the risk of bias grading of the studies included in this systematic review in our first report (9). The overall grading indicates that almost all of the studies (n = 48) had a “moderate” grading, while only one study had “strong” grading.

Frequency of food allergy
The detailed results of the frequencies of the different food allergies are shown in Tables E1 & E2. Table E3 shows the summarized ranges of frequencies for each food allergy for the different age groups (<1, 2-5, 6-17, ≥18 years) according to the different assessment methods used to measure food allergy. Estimates in Table E3 are the lifetime prevalence for self-reported food allergy and point prevalence for all assessment methods. The pooled prevalence estimates of the specific food allergies are shown in Figures 1-8 and Figures E2-E9. There was significant heterogeneity between the studies when pooled together regardless of the assessment method used.

Cow’s milk allergy
The detailed estimates of the frequency of cow’s milk allergy are presented in Table E1 and range of estimates in Table E3. Across all assessment methods and age groups, the prevalence of cow’s milk allergy varied across studies, the greatest variation seen in point prevalence of self-reported cow’s milk allergy. The range of point prevalence of food-challenged cow’s milk allergy was the same for all age groups (0.0%-3.0%) (Table E3). The pooled age-stratified prevalence estimates of cow’s milk allergy according to the different assessment methods are shown in Figure 1 and the region-stratified estimates are shown in Figure E2. The overall lifetime prevalence of self-reported cow’s milk allergy was 6.0% (95% CI 5.7-6.4). The overall point prevalence of self-reported cow’s milk allergy was 2.3% (95% CI 2.1-2.5); 0.3% (95% CI 0.03-0.6) for SPT positivity; 4.7 (95% CI 4.2-5.1) for specific-IgE positivity; 0.6% (95% CI 0.5-0.8) for FC positivity; and 1.6% (95% CI 1.2-1.9) for FC or history of cow’s milk allergy. In most cases these estimates were usually higher in younger age groups than older ones (Figure 1). The region-stratified estimates show that in most cases, the estimates of cow’s milk allergy according to each assessment method were higher in Northern Europe than in other regions (Figure E2).

Egg allergy
Frequency estimates of hen’s egg allergy are shown in Table E1 and the range of estimates in Table E3. The ranges of the prevalence estimates of egg allergy were comparable across the age groups regardless of the assessment method used, but varied widely between studies (Table E3). The pooled age-stratified prevalence estimates of egg allergy according to the different assessment methods are shown in Figure 2 and the region-stratified estimates are shown in Figure E3. The overall lifetime prevalence of self-reported egg allergy was 2.5% (95% CI 2.3-2.7). The overall point prevalence of self-reported egg allergy was 1.5% (95% CI 1.3-1.6); 0.8% (95% CI 0.6-0.9) for SPT positivity; 3.6 (95% CI 3.2-4.0) for specific-IgE positivity; 0.2% (95% CI 0.2-0.3) for FC positivity; and 1.0% (95% CI 0.8-1.3) for FC or history of egg allergy. The estimates were usually higher in younger age groups than older ones (Figure 2), while the region-stratified estimates were highest in Northern Europe (Figure E3).

Wheat allergy
Frequency estimates of wheat allergy are shown in Table E1 and the range of estimates in Table E3. The ranges of the prevalence estimates of wheat allergy were also comparable across the age groups regardless of the assessment method used, but varied between studies (Table E3). The overall pooled estimate of wheat allergy was 3.6% (95% CI 3.0-4.2) for lifetime self-reported prevalence; 1.5% (95% CI 1.3-1.8) for point self-reported prevalence; 0.7% (95% CI 0.4-1.0) for SPT positivity; 3.9 (95% CI 3.4-4.4) for specific-IgE positivity; 0.1% (95% CI 0.01-0.2) for food challenge positivity; and 0.3% (95% CI 0.02-0.6) for food challenge or history of wheat allergy. Although in most cases, the estimates appeared higher in older age groups than younger ones, the data were insufficient to compare the between age groups as in many cases only one study was available for a particular age group (Figure 3). The region-stratified estimates were higher in Northern Europe for lifetime and point self-reported prevalence, but higher in Southern Europe for point prevalence of SPT positivity and in Western Europe for specific-IgE positivity, FC positivity and FC or history of wheat allergy (Figure E4).

Soy allergy
Frequency estimates of soy allergy are shown in Table E1 and the range of estimates in Table E3. For each assessment method, the ranges of the prevalence...
estimates of soy allergy were comparable across the age groups and between studies, although some notable variations between studies were seen for specific-IgE positivity (Table E3). Only one study each was eligible for pooling for lifetime self-reported prevalence and SPT positivity, and no study for FC or history of soy allergy, hence no pooled estimates are presented for these assessment methods. The overall pooled point prevalence of self-reported soy allergy was 1.5% (95% CI 1.2-1.8); 3.2% (95% CI 2.7-3.6) for specific-IgE positivity; and 0.3% (95% CI 0.1-0.4) for FC positivity. Although estimates appeared higher in younger children than the older age groups, there were insufficient data to compare the pooled estimates between age groups as in most cases only one study was available for a particular age group (Figure 4). The region-stratified estimates showed that all studies on point self-reported prevalence of soy allergy were undertaken only in Northern Europe, while others were done only in Northern and Western Europe. The point prevalence of specific-IgE positivity and FC positivity were higher in Western than Northern Europe (Figure E5).

**Peanut allergy**

Frequency estimates of peanut allergy are shown in Table E2 and the range of estimates in Table E3. For each assessment method, the ranges of prevalence estimates of peanut allergy were comparable across age groups, but there were variations between studies particularly with regards to specific-IgE positivity (Table E3). The overall lifetime prevalence of self-reported peanut allergy was 0.4% (95% CI 0.3-0.6); 1.7% (95% CI 1.5-1.8) for self-reported point prevalence; 1.7% (95% CI 1.6-1.9) for SPT positivity; 8.6% (95% CI 8.2-9.0) for specific-IgE positivity; 0.2% (95% CI for 0.2-0.3) for FC positivity; and 1.6% (95% CI 1.2-1.9) for FC or history of peanut allergy. In most cases the estimates were higher in older age groups than in younger children (Figure 5), while the region-stratified estimates were mostly higher in Western than Northern Europe (Figure E6).

**Tree nut allergy**

Frequency estimates of tree nut allergy are shown in Table E2 and the range of estimates in Table E3. Generally, the ranges of prevalence estimates for each assessment method of tree nut allergy were comparable across age groups, except for SPT positivity where the estimates appeared much higher in the older age groups. There were no studies on specific-IgE assessment of tree nut allergy among children 17 years and younger. Variations between studies were particularly seen with regards to specific-IgE positivity, and SPT positivity (Table E3). Only one study was eligible for pooling with regards to assessment of tree nut allergy based on specific-IgE positivity, hence no pooled estimates were presented for specific-IgE positivity. The overall lifetime prevalence of self-reported tree nut allergy was 1.3% (95% CI 1.2-1.5); 1.8% (95% CI 1.6-2.0) for point self-reported prevalence; 0.6% (95% CI 0.5-0.7) for SPT positivity; 0.5% (95% CI for 0.08-0.8) for FC positivity; and 0.1% (95% CI 0.1-0.2) for FC or history of tree nut allergy. The estimates were higher in older age groups than in younger children (Figure 6), while the region-stratified estimates were mostly higher in Northern Europe than in other regions (Figure E7).

**Fish allergy**

Frequency estimates of fish allergy are shown in Table E2 and the range of estimates in Table E3. The ranges of prevalence estimates for each assessment method of fish allergy were comparable across age groups and wide variations were seen between studies based on lifetime and point self-reported prevalence of fish allergy (Table E3). The overall lifetime prevalence of self-reported fish allergy was 2.2% (95% CI 1.8-2.5); 0.6% (95% CI 0.5-0.7) for point self-reported prevalence; 0.7% (95% CI for 0.4-0.9) for specific-IgE positivity; 0.1% (95% CI 0.02-0.2) for FC positivity; and 0.1% (95% CI 0.01-0.2) for FC or history of fish allergy. The estimates were higher in younger age groups with regards to lifetime self-reported prevalence and specific-IgE positivity, but higher in older age groups based on other assessment methods (Figure 7). The region-stratified estimates were highest in Northern Europe (Figure E8).

**Shellfish allergy**

Frequency estimates of shellfish allergy are shown in Table E2 and the range of estimates in Table E3. There were no studies on lifetime self-reported prevalence of shellfish allergy among children ≤ 5 years, on specific-IgE positivity among children ≤ 17 years and younger, and no studies altogether on FC or history among all age groups. The ranges of prevalence estimates for each assessment method of shellfish allergy were comparable across age groups and wide variations were
seen between studies based on point prevalence of self-reported shellfish allergy (Table E3). In pooling, there were no eligible studies on SPT positivity, specific-IgE positivity, and FC or history; hence pooled estimates are not presented for these assessment methods. The overall lifetime prevalence of self-reported shellfish allergy was 1.3% (95% CI 0.9–1.7); 0.7% (95% CI 0.6–0.8) for point self-reported prevalence; and 0.1% (95% CI 0.06–0.3) for FC positivity. The estimates were higher in older age groups than in younger age groups (Figure 8). All studies on lifetime self-reported prevalence of shellfish allergy were undertaken in Western Europe, while studies on point prevalence of self-reported shellfish allergy and FC positivity were undertaken only in Western and Northern Europe. While the pooled estimates for self-reported point prevalence of shellfish allergy was higher in Northern Europe, the estimates were comparable between the two regions with regards to FC positivity (Figure E9).

**DISCUSSION**

**Statement of main findings**

This synthesis of studies provides the most comprehensive and up-to-date estimates of the frequency of the eight most common specific food allergies across different age groups and geographical regions in Europe. Overall, most studies were graded as at “moderate” risk of bias, taking into account appropriateness of the study design, potential for selection bias, and exposure and outcome assessments methods used. Most of the studies were undertaken among children, usually those less than 18 years old. Only a few studies were done in Eastern and Southern Europe compared to studies from Western and Northern Europe.

The overall pooled lifetime self-reported prevalence was highest for cow’s milk allergy (6.0%) and lowest for soy allergy (0.3%). The point prevalence of self-reported was also highest for cow’s milk allergy (2.3%) but lowest for fish allergy (0.6%). Based on objectively verified FC, the prevalence was also highest for cow’s milk allergy (0.6%) and lowest for wheat and shellfish allergies, both each having 0.1% prevalence. Generally, the prevalence of cow’s milk allergy and egg allergy were higher in younger age groups than older age groups, while the prevalence of peanut allergy, tree nut allergy, fish allergy, and shellfish allergy were higher in the older age groups than the younger age groups. There were insufficient data to compare the estimates of soy and wheat allergy between the age groups as in most cases only one study was available for particular age group. The prevalence of cow’s milk allergy, egg allergy, wheat allergy, tree nut allergy, fish allergy, and shellfish allergy were in general higher in Northern Europe than other regions, while the prevalence of soy allergy and peanut allergy were higher in Western Europe than in other regions.

**Strengths and limitations**

In addition to the rigorous steps undertaken to produce the current synthesis, other strengths of the review include a comprehensive literature search that covered the major electronic databases, although we cannot rule out the possibility that our search terms might have missed some relevant articles; no language restriction; and systematic and painstaking screening and appraisal of the primary studies included. We however limited the period of the review to studies published only in Europe between 2000 and 2012 due to the large quantity of studies found at the initial search; this will limit the generalizability of findings beyond the period in focus and outside Europe. We observed significant heterogeneity between the studies, which might indicate important differences between studies in terms of study design and methods used to measure food allergy, particularly FC and SPT methodologies. There were also wide variations in participation rates across studies, ranging between 17.3% to 99.5%, while in several studies, neither the participation rates were reported nor were there adequate information provided to allow for recalculation, thus indicating potential selection bias in several of the studies. These methodological limitations will influence the estimates of the frequency of food allergies reported from this pooled analysis, most likely the pooled estimates are underestimates of the actual frequencies. We therefore recommend that caution should be exercised in interpreting these results. Unexpectedly, the point prevalence estimates of peanut and tree nut allergies were greater than their lifetime prevalence estimates. Although one reason for this discrepancy is that the estimates of lifetime and point prevalence came from different studies, a more plausible explanation is that this underscores the need for consistent study designs and reporting of results in future studies.

To our knowledge, this is the first study providing
Figure 1 Age-stratified pooled prevalence of cow’s milk allergy (CMA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Figure 2  Age-stratified pooled prevalence of egg allergy (EA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Table 1: Overall pooled prevalence (I-squared = 97.4%, p = 0.000)

<table>
<thead>
<tr>
<th>Age group</th>
<th>Study</th>
<th>Cases/Participants</th>
<th>Percentage (95% CI)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-5 years old</td>
<td>Pythoian (ref. 60)</td>
<td>137/3308</td>
<td>4.10 (3.50, 4.90)</td>
<td>84.11</td>
</tr>
<tr>
<td>6-17 years old</td>
<td>Caffaroli (ref. 14)</td>
<td>6/625</td>
<td>1.00 (0.40, 2.10)</td>
<td>15.89</td>
</tr>
<tr>
<td>Overall (I-squared = 97.4%, p = 0.000)</td>
<td></td>
<td></td>
<td>3.61 (3.00, 4.21)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Figure 3  Age-stratified pooled prevalence of wheat allergy (WA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Figure 4  Age-stratified pooled prevalence of soy allergy (SA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Prevalence of common food allergies in Europe

Figure 5 Age-stratified pooled prevalence of peanut allergy (PA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Figure 6  Age-stratified pooled prevalence of tree nut allergy (TNA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
Prevalence of common food allergies in Europe

Figure 7 Age-stratified pooled prevalence of fish allergy (FA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
**Figure 8**  Age-stratified pooled prevalence of shellfish allergy (SFA) in studies published in Europe between January 2000 and September 2012. Markers represent percentages and 95% CI and boxes represent study size.
comprehensive estimates of the prevalence of the most common specific food allergies across the different geographical regions of Europe and well-defined age groups. The observed regional differences in the estimates of the different food allergies may indicate the importance of spatial distributions of the diseases; hence, spatial distributions of food allergies should be considered in future studies. The observed regional differences may also reflect the variations and non-standardized methods applied in the assessment of food allergies across the different European settings. Very few studies were undertaken in Eastern and Southern Europe, possibly a true reflection of fewer studies done in these settings in this evidence base or that most studies are published in local journals and not indexed in the databases included in our search. Clearly more studies are required from these regions in order to establish the putative frequency of food allergies.

A further strength of this study is that we were able to analyze all possible methods that have been used to measure food allergy, including self-report, SPT, specific IgE sensitization, FC, and the various combination of these measures, particularly FC or convincing clinical history. However, because of the wide variations in the definition of food allergies based on each of these methods, particularly the cut-off points used to define IgE or SPT sensitization to food allergens across the studies, comparison of estimates across studies is challenging. As indicated in our previous report (Chapter 1.1) (9), we were interested in estimating the frequency of IgE-mediated and non-IgE-mediated phenotypes of food allergy, but this was not feasible as most studies failed to make clear the different phenotypes of food allergy studied. The methodological grading of most of the studies was moderate, and as we also noted earlier (9), there is an opportunity to improve the methodological quality of studies across all regions. In particular, more systematic application of established standard methods for assessment of food allergy across populations would improve the measurement of food allergies and allow for better comparison between studies.

Comparison of our findings with previous studies

Only three previous systematic reviews (15, 65, 80) have examined the prevalence of food allergies, however, comparison of our findings is primarily made with regards to two of these studies (65, 80) as the third study (15) presented estimates already given in one of the studies (65). Rona and colleagues (65) presented range of estimates that are to great extent comparable to the ranges of estimates we have reported in this study. It was not however clear if the self-reported estimates in that study were lifetime prevalence or point prevalence. In the study by Zuidmeer et al. (80), the pooled self-reported prevalence of wheat allergy among adults was 0.4% and 2.1% for point prevalence of specific IgE sensitization, although it was not also clear if the self-reported estimates were lifetime or point prevalence. The point prevalence of self-reported wheat allergy in the current study among adults was 1.5%, whereas we did not find any eligible studies for pooling among adults based on specific IgE sensitization to wheat. Among children, Zuidmeer and colleagues presented pooled self-reported prevalence of tree nut allergy of 0.5%, soy allergy of 0.3%, and SPT positivity to wheat of 0.4%. In our study, the corresponding point prevalence of self-reported tree nut allergy among children was up to 1.8%, up to 4.2% for soy allergy, and 3.9% SPT positivity to wheat, much greater estimates than the estimates given by Zuidmeer and colleagues (80). Similar to our observation, the prevalence of tree nuts compared to other allergies was higher among adults than in children in the study by Zuidmeer and colleagues (80), possibly indicating difference in timing of introduction of these foods. Some of the discrepancies between our estimates and those of the previous reviews could be explained by the fact that the previous reviews included studies from all parts of the world whereas our study was limited only to Europe. In addition, the previous reviews included studies from 1990 whereas the earliest studies in our review were those published in 2000.

Conclusions

The current study has provided so far the most comprehensive and up-to-date estimates of the eight most common food allergies across different age groups and regions in Europe. Overall, at least 1 in 20 children are believed by parents to have had one or more food allergy in their lifetime. Dairy products are the most commonly implicated foods by parents than other foods. There was up to 10-fold difference between self-reported and challenge-verified prevalence of food allergy, with these being most
marked for wheat, tree nut, egg, shellfish, and least for tree nut. This discrepancy, particularly for milk, soy, and wheat, may be due in part to non-IgE-mediated food allergy. The prevalence of food allergy varied by age groups and European regions. Further studies will improve this evidence base by employing standardized methodology for the assessment of food allergies across populations and initiating strategies that will increase participation rates across studies.

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EAACI

**Contributorship**
AS, AM and GR conceived this review. It was undertaken by BN and LH, with the support of SSP. BN, LH, and AS led the drafting of the manuscript and all authors critically commented on drafts of the manuscript.

**Conflicts of interest**
None known

**References**


53. Ostblom E, Wickman M, van Hage M, Lilja G. Reported symptoms of food hypersensitivity and sensitization
1.3

THE DIAGNOSIS OF FOOD ALLERGY
SYSTEMATIC REVIEW AND META-ANALYSIS

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Background: We investigated the accuracy of tests used to diagnose food allergy.

Methods: Skin prick tests (SPT), specific-IgE (sIgE), component-resolved diagnosis (CRD) and the atopy patch test (APT) were compared with the reference standard of double-blind, placebo-controlled food challenge. Seven databases were searched and international experts were contacted. Two reviewers independently identified studies, extracted data and used QUADAS-2 to assess risk of bias. Where possible, meta-analysis was undertaken.

Results: 24 (2,831 participants) studies were included. For cows’ milk allergy, the pooled sensitivities were 53% (95% CI 33-72), 88% (95% CI 76-94) and 87% (95% CI 75-94), and specificities were 88% (95% CI 76-95), 68% (95% CI 56-77) and 48% (95% CI 36-59) for APT, SPT, slgE, respectively. For egg, pooled sensitivities were 92% (95% CI 80-97) and 93% (95% CI 82-98), and specificities were 58% (95% CI 49-67) and 49% (40% to 58%) for skin prick tests and specific-IgE. For wheat, pooled sensitivities were 73% (95% CI 56-85) and 83% (95% CI 69-92), and specificities were 73% (95% CI 48-89) and 43% (95% CI 20% to 69%) for SPT and slgE. For soy, pooled sensitivities were 55% (95% CI 33-75) and 83% (95% CI 64-93), and specificities were 68% (95% CI 52-80) and 38% (95% CI 24-54) for SPT and slgE. For peanut, pooled sensitivities were 95% (95% CI 88-98) and 96% (95% CI 92-98), and specificities were 61% (95% CI 47-74), and 59% (95% CI 45-72) for SPT and slgE.

Conclusions: The evidence base is limited and weak, and is therefore difficult to interpret. Overall, SPT and slgE appear sensitive though not specific for diagnosing IgE-mediated food allergy.

BACKGROUND

‘Food allergy’ refers to the subgroup of food hypersensitivity reactions (1) in which immunologic mechanisms have been implicated, whether IgE-mediated and/or non-IgE-mediated (2). The first and most important step in the diagnosis of food allergy is a full dietary history and this should be supplemented with a clinical examination.

The double-blind, placebo-controlled food challenge (DBPCFC) is usually considered the ‘gold standard’ diagnostic test (3). DBPCFC is, however, time-consuming, resource-intensive, and may induce anaphylaxis, hence there is a need to try and find safer and cheaper alternatives (3).

The most common additional tests are the skin prick test (SPT)(4), serum food-specific-IgE (specific-IgE) (5) and, to a lesser extent, component specific-IgE (6) and atopy patch testing (APT)(7). Specific-IgE and SPT indicate the presence of IgE sensitization to a specific food. Sensitization is, however, not always associated with a clinical reaction to that food (8). Non-IgE-mediated immunological reactions to food result from activation of other immunologic pathways (e.g. T-cell mediated) and manifestations include atopic eczema/dermatitis, food protein-induced enterocolitis, or proctocolitis (8). APT may be positive in some of these non-IgE mediated conditions (8).

The literature on diagnosis of food allergy currently lacks clear consensus regarding the accuracy and safety of different diagnostic approaches. This systematic review is one of seven inter-linked evidence syntheses that were undertaken in order to provide a state-of-the-art synopsis of the current evidence base. They will be used to inform the formulation of clinical recommendations in the EAACI Guidelines for Food Allergy and Anaphylaxis. This systematic review assessed the diagnostic accuracy of tests aimed at supporting the clinical diagnosis of food allergy.

METHODS

A protocol for the systematic review was developed prospectively (9) and registered with the International Prospective Register of Systematic Reviews (PROSPERO) at http://www.crd.york.ac.uk/prospero/, registration number CRD42013003707.

Search strategy

Articles were retrieved using a highly sensitive search strategy implemented in the following databases: Cochrane Library including Cochrane Database of Systematic Reviews (CDSR); Database of Reviews of Effectiveness (DARE); CENTRAL (Trials); Methods Studies; Health Technology Assessments (HTA); Economic Evaluations Database (EED); MEDLINE (OVID); Embase (OVID); CINAHL (Ebscohost); ISI Web of Science (Thomson Web of Knowledge); TRIP Database (web www.tripdatabase.com); and Clinicaltrials.gov (NIH web).

The search strategies were supplemented by contacting an international panel of experts for potential studies. There were no language restrictions, and where possible, non-English language papers were translated.

Inclusion and exclusion criteria

Prospective or retrospective, cross-sectional or case control studies that evaluated APT, SPT, specific-IgEs, and component specific-IgE in children or adults presenting with suspected food allergy caused by cow’s milk, hen’s egg, soy, peanut, tree nut, fish, or shellfish were included. The reference standard was DBPCFC used in at least 50% of the participants (Figure 1). Studies in which participants were selected based on having a positive food allergy test result (index test or reference standard) or for which no 2x2 data could be extracted were excluded.

Study selection and data extraction

Two reviewers (SSP, KSW) independently checked titles and abstracts identified by the search, followed by review of the full text for assessment of eligibility. Both reviewers also extracted data using a customized form, and assessed risk of bias using the QUADAS-2 tool (10). Any discrepancies were resolved by consensus and, where necessary, a senior reviewer (AS) was consulted. We collected study characteristics and recorded the number of true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN) for constructing a 2x2 table for each study. In cases where 2x2 data were not available, where possible we derived them from reported summary statistics such as sensitivity, specificity, and/or likelihood ratios.

Data analysis, synthesis and reporting

For each test, diagnostic accuracy was assessed
The diagnosis of food allergy

Preliminary exploratory analyses were conducted for each test by plotting pairs of sensitivity and specificity from each study on forest plots and in receiver operating characteristic (ROC) space (11). Hierarchical summary ROC (HSROC) models (12, 13) were used to summarize the accuracy of each test, and to compare the accuracy of two or more tests. Where studies used a common or similar cut-off, we used parameter estimates from the models to compute summary sensitivities and specificities with 95% confidence regions. Analyses were performed in Review Manager 5.2 (The Nordic Cochrane Centre, The Cochrane Collaboration, 2012), and SAS software (version 9.2; SAS Institute, Cary, NC).

Results

Study selection

We identified 6,260 studies (excluding duplicates) and 312 were eligible for full-text review. Twenty-four studies (33 references) (7, 45) with a total of 2,831 participants were included in the quantitative analyses. Figure E1 in the online supplement shows the PRISMA flowchart for the study screening and selection process.

Characteristics of included studies

Table 1 summarizes the characteristics and methodological quality of the 24 included studies. Of the 24 studies, 17 were conducted in Europe. Twenty-two studies were cohort studies and 2 were case-control studies. The majority (n=21) included infants or children under 18 years of age. At the study entry all participants in six studies had atopic eczema/dermatitis. Eight studies reported data on more than one target food. Most studies were judged to be at high or unclear risk of bias in all domains except flow and timing. Applicability concerns were judged as high mainly in the index test domain because in 18 studies, there was prior testing with SPT and/or specific-IgE when a diagnosis of food allergy was suspected. Further details are available in the online supplement.

Main findings

Table 2 shows summary results for each target food where meta-analysis was possible.

Cow’s milk: Figure E2 shows the pairs of sensitivity and specificity from each study, including the cut-offs used, for APT (3 studies), SPT (6 studies), and specific-IgE (6 studies). The summary sensitivity and specificity of APT were 53% (95% CI 33% to 72%) and 88% (76% to 95%). For SPT and specific-IgE, the summary sensitivities were 88% (76% to 94%) and 87% (75% to 94%), and specificities were 68% (56% to 77%) and 48% (36% to 59%), respectively. Although there was some between-study heterogeneity, the summary estimates suggest that specific IgE detects on average the same number of cases per 100 people with cow’s milk allergy as SPT, but gives on average 20 additional false positive diagnoses for every 100 people without the allergy (p<0.01).
<table>
<thead>
<tr>
<th>First author, year (reference)</th>
<th>Study design</th>
<th>Sample size</th>
<th>Foods evaluated</th>
<th>Population</th>
<th>Index test(s) (definition of a positive result)</th>
<th>Reference standard (participants)</th>
<th>QUADAS-2 domains*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alessandri, 2012 (43)</td>
<td>Cohort</td>
<td>68</td>
<td>Hen's egg</td>
<td>Children suspected of HE allergy based on reported history of reactions and positive SPT or SIgE to HE white extracts.</td>
<td>Fresh and commercial SPT (recorded as wheal areas and expressed in mm²); SIgE ImmunoCAP (optimal cut off points); Detection of Gal d 1, Gal d 2, Gal d 3 and Gal d 5 (ISAC 103 microarray test)</td>
<td>DBPCFC (n=68)</td>
<td></td>
</tr>
<tr>
<td>Ando, 2008 (40)</td>
<td>Cohort</td>
<td>108</td>
<td>Hen's egg</td>
<td>Children suspected of egg allergy</td>
<td>SIgE ImmunoCAP (≥ 0.35 kUA/L and optimal cut off points)</td>
<td>DBPCFC (n=108)</td>
<td></td>
</tr>
<tr>
<td>Ayuso, 2012 (24, 27)</td>
<td>Cohort</td>
<td>37</td>
<td>Shrimp</td>
<td>Children and adults reporting immediate allergic reactions following shrimp ingestion</td>
<td>Fresh SPT (not reported); SIgE ImmunoCAP (≥ 0.35 kU/L); APT (erythema with an infiltration)</td>
<td>DBPCFC (n=31); OFC (n=21)</td>
<td></td>
</tr>
<tr>
<td>Breuer, 2004 (42)</td>
<td>Cohort</td>
<td>64</td>
<td>Cow’s milk, hen’s egg, wheat, soybean</td>
<td>Children with moderate to severe AD</td>
<td>SIgE CAP RAST FEIA (≥ 0.35 kU/L); APT (erythema with an infiltration)</td>
<td>106 DBPCFC (n=64)</td>
<td></td>
</tr>
<tr>
<td>Caffarelli, 1995 (38)</td>
<td>Case control</td>
<td>33</td>
<td>Hen’s egg</td>
<td>Children who as infants had food allergy</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE RAST (a score of ++, range 0-4)</td>
<td>DBPCFC (n=33)</td>
<td></td>
</tr>
<tr>
<td>Daul, 1988 (36)</td>
<td>Cohort</td>
<td>30</td>
<td>Shrimp</td>
<td>Adults with symptoms within 1 hour of ingestion</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgERAST (&gt;3% label bound)</td>
<td>DBPCFC (n=30)</td>
<td></td>
</tr>
<tr>
<td>Dieguez, 2009 (39)</td>
<td>Cohort</td>
<td>157</td>
<td>Hen’s egg</td>
<td>Children with allergy to egg</td>
<td>Commercial yolks and whites SPT (wheal diameter ≥ 3 mm); SIgE FEIA (≥ 0.35 kU/L)</td>
<td>159 DBPCFC (n=159)</td>
<td></td>
</tr>
<tr>
<td>Eigenmann, 1998 (31)</td>
<td>Case control</td>
<td>Not reported</td>
<td>Cow’s milk, hen’s egg, wheat, soybean, peanut</td>
<td>Children with AD suspected of IgE-mediated allergies to egg, milk, peanut, soybean, and/or wheat</td>
<td>Commercial SPT (mean diameter / surface area of wheal: 4 mm / 16 mm² for egg, 5 mm / 29 mm² for milk, 6 mm / 40 mm² for peanut, 3 mm / 57 mm² for soy, and 3 mm / 7 mm² for wheat)</td>
<td>DBPCFC (not clear whether participants received same reference standard)</td>
<td></td>
</tr>
<tr>
<td>Flinterman, 2006 (29)</td>
<td>Cohort</td>
<td>27</td>
<td>Peanut</td>
<td>Children with peanut sensitization</td>
<td>Commercial SPT (not reported, we assumed wheal diameter ≥ 3 mm) SIgE CAP system FEIA (≥ 0.35 IU/mL)</td>
<td>DBPCFC (n=27)</td>
<td></td>
</tr>
<tr>
<td>Flinterman, 2008 (32)</td>
<td>Cohort</td>
<td>26</td>
<td>Tree nuts</td>
<td>Children with tree nut sensitivity</td>
<td>SIgE CAP- FEIA (≥ 0.35 kU/L) IMB SDS-Page</td>
<td>DBPCFC (n=26)</td>
<td></td>
</tr>
<tr>
<td>Glaumann, 2012 (25)</td>
<td>Cohort</td>
<td>43</td>
<td>Peanut</td>
<td>Children with suspected peanut allergy</td>
<td>SIgE ImmunoCAP (≥ 0.1kUA/l) CD-Sens</td>
<td>DBPCFC (n=38)</td>
<td></td>
</tr>
<tr>
<td>Isolauri, 1996 (15)</td>
<td>Cohort</td>
<td>183</td>
<td>Cow’s milk</td>
<td>Children with AD not suspected of cow’s milk allergy</td>
<td>APT (significant erythema, or erythema with edema or eczema); Commercial SPT (≥ 1/2 the histamine reactions size)</td>
<td>DBPCFC (n=118) or OFC (n=65)</td>
<td></td>
</tr>
<tr>
<td>Keskin, 2005 (16)</td>
<td>Cohort</td>
<td>37</td>
<td>Cow’s milk</td>
<td>Children with suspected cow’s milk allergy</td>
<td>APT (erythema with infiltration and papulation); Commercial SPT (wheal diameter ≥ 3 mm); SIgE ImmunoCAP (≥ 0.7kU/L)</td>
<td>DBPCFC (n=31)</td>
<td></td>
</tr>
<tr>
<td>First author, year (reference)</td>
<td>Study design</td>
<td>Sample size</td>
<td>Population</td>
<td>Foods evaluated</td>
<td>Index test(s) (definition of a positive result)</td>
<td>Reference standard (participants)</td>
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<tr>
<td>Masthoff, 2012 (26)</td>
<td>Cohort</td>
<td>172</td>
<td>Children with history suggestive of tree nut allergy</td>
<td>Tree nuts</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE ImmunoCap (≥ 0.35 kUA/L); FEIA and ImmunoCap (≥ 0.35 kUA/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>Mehli, 2006 (6, 14, 22, 34)</td>
<td>Cohort</td>
<td>437</td>
<td>Children with suspected food allergy</td>
<td>Cow’s milk, hen’s egg, soybean</td>
<td>Fresh &amp; commercial SPT (wheal diameter ≥ 3 mm); SIgECAP-FEIA (≥ 0.35 kU/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>Ortolani, 2000 (21, 30)</td>
<td>Cohort</td>
<td>86</td>
<td>Children with history suggestive of tree nut allergy</td>
<td>Tree nuts</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgECAP-FEIA (≥ 0.7 kU/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>Rancé, 2000 (17, 28, 33, 35)</td>
<td>Cohort</td>
<td>98</td>
<td>Children with AD</td>
<td>Cow’s milk, hen’s egg, soybean, peanut, fish, pork, chicken</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE CAP-FEIA (&gt; 0.35 kUA/L); DBPCFCs (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>Sampson, 1984 (20, 45)</td>
<td>Cohort</td>
<td>30</td>
<td>Children with suspected food allergy</td>
<td>Cow’s milk, hen’s egg, soybean, peanut, shellfish/fish</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE RAST (&gt;0.5% of radioactivity); DBPCFCs (n= 172)</td>
<td>DBPCFCs</td>
<td></td>
</tr>
<tr>
<td>Sampson, 1997 (37)</td>
<td>Cohort</td>
<td>196</td>
<td>Children with AD</td>
<td>Cow’s milk, hen’s egg, soybean, peanut, shellfish/fish</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE CAP-FEIA (≥0.35 kUA/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>Sampson, 2001 (18)</td>
<td>Cohort</td>
<td>103</td>
<td>Children</td>
<td>Cow’s milk, hen’s egg, soybean, peanut, tree nuts</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE CAP-FEIA (&gt; 0.35 kUA/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>Scibilia, 2006 (41)</td>
<td>Cohort</td>
<td>27</td>
<td>Children</td>
<td>Wheat</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE CAP-FEIA (&gt; 0.35 kUA/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>van den Berg, 2012 (41)</td>
<td>Cohort</td>
<td>396</td>
<td>Children with suspected peanut allergy</td>
<td>Cow’s milk, hen’s egg, peanut, tree nuts</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE CAP-FEIA (&gt; 0.35 kUA/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
<tr>
<td>van Nieuwaeil, 2010 (23)</td>
<td>Cohort</td>
<td>103</td>
<td>Children</td>
<td>Peanut</td>
<td>Commercial SPT (wheal diameter ≥ 3 mm); SIgE CAP-FEIA (&gt; 0.35 kUA/L); DBPCFC (n= 172)</td>
<td>DBPCFC</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1 (Continued)***

* Risk of Bias 1 2 3 4 ; Applicability 1 2 3 4 . Risk of Bias is assessed for each domain of the QUADAS-2 tool but concerns about applicability is only assessed for 3 of the 4 domains (the flow and timing domain is not assessed). Applicability concerns regarding applicability of a study to the review question. Low risk of bias or low applicability concern (green); Unclear risk of bias or unclear applicability concern (yellow); High risk of bias or high applicability concern (red).
Table 2  Summary estimates of the accuracy of atopy patch test (APT), skin prick test (SPT), and specific-IgE for each target food

<table>
<thead>
<tr>
<th>Test (cut-off)</th>
<th>Studies</th>
<th>Participants</th>
<th>Cases</th>
<th>Sensitivity % (95% CI)</th>
<th>Specificity % (95% CI)</th>
<th>Positive likelihood ratio (95% CI)</th>
<th>Negative likelihood ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COW’S MILK: FIVE PROSPECTIVE COHORTS (8, 15, 16, 20, 44), TWO RETROSPECTIVE COHORTS (37, 42), ONE RETROSPECTIVE CASE CONTROL STUDY (30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APT (≥3mm)</td>
<td>5</td>
<td>587</td>
<td>284</td>
<td>87.9 (75.6, 94.4)</td>
<td>67.5 (56.0, 77.2)</td>
<td>2.70 (2.09, 3.50)</td>
<td>0.18 (0.10, 0.34)</td>
</tr>
<tr>
<td>Specific-IgE (mixed cut-offs)</td>
<td>6</td>
<td>831</td>
<td>390</td>
<td>87.3 (75.2, 93.9)</td>
<td>47.7 (36.4, 59.2)</td>
<td>1.67 (1.44, 1.93)</td>
<td>0.27 (0.16, 0.45)</td>
</tr>
<tr>
<td>Ratio¹</td>
<td></td>
<td></td>
<td></td>
<td>1.0 (0.93, 1.06), P=0.9</td>
<td>0.71 (0.60, 0.83), P&lt;0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEN’S EGG: THREE PROSPECTIVE COHORTS (8, 20, 4), ONE RETROSPECTIVE COHORT (37), ONE PROSPECTIVE CASE-CONTROL STUDY (38), ONE RETROSPECTIVE CASE-CONTROL STUDY (31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT (mixed cut-offs)</td>
<td>5</td>
<td>448</td>
<td>287</td>
<td>92.4 (79.9, 97.4)</td>
<td>58.1 (49.1, 66.6)</td>
<td>2.30 (1.77, 2.74)</td>
<td>0.13 (0.05, 0.36)</td>
</tr>
<tr>
<td>Specific-IgE (mixed cut-offs)</td>
<td>5</td>
<td>572</td>
<td>346</td>
<td>93.4 (82.1, 97.8)</td>
<td>49.2 (40.2, 58.1)</td>
<td>1.84 (1.52, 2.21)</td>
<td>0.13 (0.05, 0.38)</td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
<td></td>
<td></td>
<td>1.01 (0.70, 0.96), P=0.7</td>
<td>0.85 (0.68, 1.05), P=0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHEAT: THREE PROSPECTIVE COHORTS (8, 20, 41), TWO RETROSPECTIVE COHORTS (36, 41), ONE RETROSPECTIVE CASE-CONTROL STUDY (31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT (≥3mm)</td>
<td>5</td>
<td>350</td>
<td>114</td>
<td>72.6 (55.7, 84.8)</td>
<td>73.3 (47.9, 89.1)</td>
<td>2.72 (1.32, 5.60)</td>
<td>0.37 (0.23, 0.60)</td>
</tr>
<tr>
<td>Specific-IgE (mixed cut-offs)</td>
<td>4</td>
<td>408</td>
<td>102</td>
<td>83.2 (69.0, 91.7)</td>
<td>42.7 (19.8, 69.1)</td>
<td>1.45 (0.95, 2.22)</td>
<td>0.39 (0.20, 0.77)</td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
<td></td>
<td></td>
<td>1.15 (0.97, 1.36), P=0.1</td>
<td>0.58 (0.40, 0.85), P&lt;0.01</td>
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<td></td>
</tr>
<tr>
<td>SOY: TWO PROSPECTIVE COHORTS (8, 20), ONE RETROSPECTIVE COHORT (37), ONE RETROSPECTIVE CASE-CONTROL STUDY (31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT (≥3mm)</td>
<td>4</td>
<td>366</td>
<td>94</td>
<td>55.0 (33.2, 75.0)</td>
<td>68.0 (52.4, 80.3)</td>
<td>1.71 (1.29, 2.27)</td>
<td>0.66 (0.47, 0.94)</td>
</tr>
<tr>
<td>Specific-IgE (mixed cut-offs)</td>
<td>3</td>
<td>404</td>
<td>74</td>
<td>82.9 (63.8, 93.0)</td>
<td>38.0 (24.2, 54.0)</td>
<td>1.34 (1.13, 1.58)</td>
<td>0.45 (0.24, 0.83)</td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
<td></td>
<td></td>
<td>1.51 (1.10, 2.07), P=0.01</td>
<td>0.56 (0.43, 0.72), P&lt;0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEANUT: FIVE PROSPECTIVE COHORTS (19, 20, 23, 29, 44), ONE RETROSPECTIVE COHORT (37), ONE RETROSPECTIVE CASE-CONTROL STUDY (31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT (≥3mm)</td>
<td>5</td>
<td>499</td>
<td>245</td>
<td>94.7 (87.9, 97.8)</td>
<td>61.0 (46.6, 73.6)</td>
<td>2.43 (1.69, 3.48)</td>
<td>0.09 (0.04, 0.21)</td>
</tr>
<tr>
<td>Specific-IgE (mixed cut-offs)</td>
<td>5</td>
<td>817</td>
<td>452</td>
<td>96.3 (91.6, 98.4)</td>
<td>59.3 (45.4, 72.0)</td>
<td>2.37 (1.69, 3.32)</td>
<td>0.06 (0.03, 0.15)</td>
</tr>
<tr>
<td>Ratio</td>
<td></td>
<td></td>
<td></td>
<td>1.02 (0.97, 1.06), P=0.5</td>
<td>0.97 (0.84, 1.12), P=0.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Ratio of the summary sensitivity of specific-IgE to that of SPT, and ratio of the summary specificity of specific-IgE to that of SPT. P-values were obtained from Wald tests.

Where studies reported multiple cut-offs, only results for the lowest cut-off was chosen for inclusion in the meta-analysis so that the same population was included only once for each test. Where assumptions were made regarding the use of mixed cut-offs, e.g., SPT data from studies which used cut-offs between ≥3mm and ≥4mm, and specific-IgE data from studies which used cut-offs between >0.35 kU/L or not reported, these cut-offs were considered clinically similar enough to be included in the meta-analysis of each test in order to produce summary estimates. Data for APT are shown for cow’s milk only because at least three studies reported this test. Meta-analysis was not performed for tree nuts, fish and shellfish due to the limited number of studies and substantial variation in specificity.
Hen’s egg: Figure E3 shows the pairs of sensitivity and specificity from each study for APT (1 study), SPT (5 studies), and specific-IgE (5 studies) at the different cut-offs reported. The sensitivity and specificity of APT in the single study were 41% (32% to 50%) and 88% (77% to 95%). For SPT and specific-IgE, the summary sensitivities were 92% (80% to 97%) and 93% (82% to 98%), and specificities were 58% (49% to 67%) and 49% (40% to 58%), respectively. No significant differences in sensitivity and/or specificity were observed when SPT was compared to specific-IgE (Table 2).

Wheat: Figure E4 shows the pairs of sensitivity and specificity from each study for APT (1 study), SPT (5 studies), and specific-IgE (5 studies) at the different cut-offs reported. The sensitivity of APT was 26% (16% to 40%) and specificity was 89% (82% to 94%) in the single study. For SPT and specific-IgE, the summary sensitivities were 73% (56% to 85%) and 83% (69% to 92%), and specificities were 73% (48% to 89%) and 43% (20% to 69%), respectively. There was a significant difference in specificity (P<0.01) with SPT having a higher specificity than specific-IgE (Table 2). The results suggest that specific-IgE detects on average 11 more cases out of every 100 people with wheat allergy than SPT, but gives on average 31 additional false positive diagnoses for every 100 people without the allergy.

Soy: Figure E5 shows the sensitivities and specificities for studies that evaluated APT (1 study), SPT (4 studies), and specific-IgE (3 studies) at the different cut-offs reported. The single study of APT reported a sensitivity of 24% (12% to 41%) and specificity of 86% (79% to 91%). For SPT and specific-IgE, the summary sensitivities were 73% (56% to 85%) and 83% (69% to 92%), and specificities were 73% (48% to 89%) and 43% (20% to 69%), respectively. Significant differences in sensitivity and specificity were observed with specific-IgE having a higher sensitivity than specific-IgE (Table 2). The results suggest that specific-IgE detects on average 11 more cases out of every 100 people with wheat allergy than SPT, but gives on average 31 additional false positive diagnoses for every 100 people without the allergy.

Peanut: The individual study estimates of sensitivity and specificity for SPT (5 studies) and specific-IgE (6 studies) are shown in Figure E6 for the different cut-offs reported. The summary sensitivities of SPT and specific-IgE were very similar (Table 2) – 95% (88% to 98%) and 96% (92% to 98%), respectively – with no significant difference between them (P=0.5). Similarly, there was no significant difference (P=0.7) between the specificities of SPT (61% [47% to 74%]) and specific-IgE (59% [45% to 72%]).

Tree nuts: Hazelnut was assessed in three prospective cohorts (26, 30, 44). At the ≥3mm cut-off, one study (30) reported SPT sensitivities of 88% and 90%, and specificities of 28% and 6% for hazelnut allergy using natural and commercial extracts, respectively (Figure E7). For specific-IgEs, sensitivities were 75% to 99% and specificities were 17% to 77%, depending on the cut-off.

Fish: One prospective cohort (20) and one retrospective cohort (37) showed sensitivities of 91% and 100%, but the same specificity of 57% for SPT at a cut-off of ≥3mm (Figure E8). For specific-IgEs, sensitivities were 67% to 94%, and specificities were 65% to 88% at different cut-offs.

Shellfish: Shrimp allergy was evaluated in two prospective cohorts (27, 36) (Figure E9). For SPT, sensitivities were 100% for both studies, and the specificities were 32% and 50%. For specific-IgE, one study (27), gave a sensitivity of 100% (80% to 100%) and specificity of 45% (23% to 68%) at a cut-off of >0.35 KU/L.

Component specific-IgE

Single studies evaluated the accuracy of component specific-IgEs for hen’s egg, peanut, tree nuts, and shellfish.

One study (43) including 68 children evaluated the accuracy of component specific-IgEs (Gal d1, 2, 3, 5) in boiled and raw eggs. The study reported cut-offs varying from 0 to 0.41 KUA/L (ISAC). The sensitivity estimates were 20% to 84% and specificities 84% to 100%.

Another study (25) including 43 children evaluated the accuracy of component specific-IgEs (Ara h2) in peanut allergy. The study reported a threshold of 16% for basophil allergen CD-sens (derived from the basophil allergen concentration). The sensitivity was 100%, and specificity of 77%.

One study (32) including 26 children evaluated the accuracy of component specific-IgEs (Cor a1, 2, 8; rCor a1, Pru p3, Bet v1) in hazelnut allergy. The study reported a cut-off of 0.35 kU/L (CAP FEIA system).
The diagnosis of food allergy

The sensitivities were 25% to 100%, and specificities 22% to 94%. An additional case control study (46) reported the percentage of people positive for rCor a1, 8; rBet v1, 2 (component specific-IgEs), but did not report enough information to calculate sensitivity or specificity.

One study (27) including 37 adults evaluated the accuracy of component specific-IgE (rPen a 1) for shrimp allergy. The estimated sensitivity was 100%, and the specificity was 80%.

Investigation of heterogeneity and sensitivity analyses

Due to the limited number of studies available for each meta-analysis, we were unable to use meta-regression to explore potential sources of heterogeneity in test performance as planned.

Discusson

We included 24 studies that evaluated the accuracy of APT, SPT, specific-IgEs, and component specific-IgEs at different cut-offs.

Our systematic review suggests that SPT and specific-IgE have good sensitivity, but poor specificity with wide variation in estimates for each of the food allergies investigated. The limited evidence available for APT suggested poor sensitivity, but good specificity. The strength of evidence on the relative accuracy of SPT and specific-IgE was weak; we relied on indirect comparisons of the two tests which may be prone to bias due to differences in population characteristics and study design. Very few studies have compared the tests head-to-head in the same population, and direct or indirect comparisons of accuracy between the other tests were not possible.

Our inclusion criteria were similar to those used in a recent RAND report (47). The main differences, however, were that we limited the inclusion criteria to studies in which at least 50% of participants received a DBPCFC to minimise verification bias, and we did not exclude studies based on language of publication. We also contacted senior researchers in the field in order to locate additional studies for inclusion in the review.

The strengths of this review include the use of internationally-recommended methods for study identification, methodological quality assessment, and meta-analysis. The main limitation was the poor reporting of primary accuracy studies. In particular, inclusion and exclusion criteria were not clearly defined, and there was lack of information on test cut-offs and details of how the tests were applied. Regarding population, the index tests evaluated in the included studies were previously used to select participants in 75% of the studies included in the quantitative analyses. A third of the studies were performed in a specific population; in eight studies all participants had atopic dermatitis, and in three all participants had asthma. These population issues impact on the generalisability of our findings. Furthermore, protocols for the index tests are likely to differ between countries, thus limiting applicability. Lastly, although DBPCFC is generally accepted as the reference standard for diagnosing food allergy, it is not widely used (48) and accounts for the exclusion of 30% of the potentially relevant studies.

Implications for patient care

This review has identified relevant evidence for different tests available for a range of foods most commonly implicated in suspected food allergy, and highlighted both the volume and strength of evidence available to guide clinical decision-making.

Direct comparisons are difficult because of the limited body of evidence in which these tests have been compared in the same population. That said, overall, this body of work indicates that SPT and specific-IgE (and probably also component specific-IgE) offer high sensitivity in relation to a range of allergens implicated in immediate IgE-mediated food allergy. There was, however, greater variation in the specificity of these tests, with specific-IgE tending to a higher rate of false positives.

Local decisions about which tests to employ and the order in which these are undertaken need to be guided by the above considerations, the comparability of the populations being cared for to those enrolled in studies (i.e. mainly high-risk populations being seen in specialist care settings), and the relative availability, safety, and costs of tests.

Implications for research

Most of the evidence in this review was derived from small studies, with a high or unclear risk of bias. Future studies should be prospective with consecutive recruitment, adequate sample sizes, and should be
representative of the population in which the tests will be used in practice (49). Head-to-head comparisons of specific-IgE, SPT, and component tests are needed to determine the relative accuracy of the tests. Test accuracy is only one aspect of the assessment of a test (50), and the balance between benefit and harm should also be assessed, ideally within a randomized controlled trial (51, 52).

**Conclusions**

SPT and specific-IgEs are sensitive, but not specific for diagnosis of food allergy, although test performance may differ between foods. However, the findings should be viewed with caution due to the limited evidence base and the paucity of good quality studies.

**Acknowledgements**

We would like to acknowledge the support of the EAACI and the EAACI Food Allergy and Anaphylaxis Guidelines Group in developing this systematic review. We would also like to thank the EAACI Executive Committee for their helpful comments and suggestions.

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EAACI

**Contributorship**

AS, AM, SSP, and GR conceived this review. It was undertaken by KS-W and YT, with the support of SSP. KS-W, YT, AS, and GR drafted the manuscript and all authors including TW, KH-S, SH, LP, RvR, and BV-B critically commented on drafts of the manuscript.

**Conflicts of interest**

None known

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1.4

ACUTE AND LONG-TERM MANAGEMENT OF FOOD ALLERGY
SYSTEMATIC REVIEW

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**Background:** Allergic reactions to food can have serious consequences. This systematic review summarizes evidence about the immediate management of reactions and longer-term approaches to minimize adverse impacts.

**Methods:** Seven bibliographic databases were searched from their inception to September 30, 2012 for systematic reviews, randomized controlled trials, quasi-randomized controlled trials, controlled clinical trials, controlled before-and-after and interrupted time series studies. Experts were consulted for additional studies. There were no language or geographic restrictions. Two reviewers critically appraised the studies using the appropriate tools. Data were not suitable for meta-analysis due to heterogeneity so were narratively synthesized.

**Results:** Eighty-four studies were included, but two-thirds were at high risk for potential bias. There was little evidence about acute management for non-life-threatening reactions. H1-antihistamines may be of benefit, but this evidence was in part derived from studies on those with cross-reactive birch pollen allergy. Regarding long-term management, avoiding the allergenic food or substituting an alternative was commonly recommended, but, apart from for infants with cow’s milk allergy, there was little high-quality research on this management approach. To reduce symptoms in children with cow’s milk allergy, there was evidence to recommend alternatives such as extensively hydrolyzed formula. Supplements such as probiotics have not proven helpful, but allergen-specific immunotherapy may be disease modifying and therefore warrants further exploration.

**Conclusions:** Food allergy can be debilitating and affects a significant number of people. However, the evidence base about acute and longer-term management is weak and needs to be strengthened as a matter of priority.
**BACKGROUND**

Food allergy affects many millions of people and is responsible for substantial morbidity, impaired quality of life and costs to the individual, family and society (1). In some cases, it may prove fatal (2). Allergy may develop to almost any food, but is triggered most commonly by cow’s milk, hen’s eggs, wheat, soy, peanuts, tree nuts, fish and seafood (3, 4). There are two main approaches to managing food allergy: those targeting immediate symptoms and those aiming to support longer-term management. This review summarizes research about strategies for the acute and long-term management of children and adults with IgE- and non-IgE-mediated food allergy.

This systematic review is one of seven inter-linked syntheses undertaken to provide a state-of-the-art synopsis of the evidence base in relation to the epidemiology, prevention, diagnosis, management, and impact on quality of life, which will be used to inform clinical recommendations in the EAACI Guidelines for Food Allergy and Anaphylaxis. The aims of the review were to examine what pharmacological and non-pharmacological interventions have been researched to (i) manage immediate non-life threatening symptoms of food allergy (i.e. acute treatment) and (ii) manage long-term symptoms and promote desensitization/tolerance (i.e. longer-term management).

**METHODS**

**Protocol and registration**

The review was registered with the International Prospective Register of Systematic Reviews. The protocol has been published previously (5) so only brief details about the methodology are provided here.

**Search strategy**

The following databases were searched: Cochrane Library; MEDLINE, Embase, CINAHL, ISI Web of Science, TRIP Database and Clinicaltrials.gov. Experts in the field were contacted for additional studies. Further details are included in the review protocol (6) (Data E1).

**Inclusion and exclusion criteria**

Studies of children or adults diagnosed with food allergy or reporting that they had food allergy were included. This included allergy where food was the primary sensitizer and pollen-associated food allergy if there was a direct diagnosis of food allergy. Studies of interventions for life-threatening manifestations were excluded because they were the focus of another review in this series (7).

Systematic reviews and meta-analyses, randomized controlled trials, quasi-randomized controlled trials, controlled clinical trials, controlled before-and-after studies and interrupted time series studies published up until September 30, 2012 were eligible. No language restrictions were applied and, where possible, relevant studies in languages other than English were translated.

**Study selection**

The titles and abstracts of articles were checked by two independent reviewers and categorized as included, not included and unsure (DdS and MG). Full text copies of potentially relevant studies were obtained and their eligibility for inclusion was independently assessed by two reviewers (DdS and MG). Any discrepancies were resolved by consensus or discussion with a third reviewer (AS).

**Risk of bias assessment**

Risk of bias was independently carried out by two reviewers (DdS and MG) using adapted versions of the Critical Appraisal Skills Programme (CASP) tool (http://www.casp-uk.net/) and the Cochrane Effective Practice and Organization of care Group (EPOC) Risk of Bias tools. An overall grading of high, medium or low quality was assigned to each study.

**Analysis, synthesis and reporting**

A customized data extraction form was used to abstract data from each study, this process being independently undertaken by two reviewers (DdS and MG). Discrepancies were resolved by discussion. Three experts in the field checked all of the data extraction for accuracy and relevance (AS, RvR, TW). Meta-analysis was not appropriate because the studies were heterogeneous in focus, design, target populations and interventions. Findings were synthesized narratively by grouping studies according to topic, design, quality and outcomes. The narrative synthesis was checked by a group of methodologists and subject experts to ensure accuracy and relevance.
RESULTS

Study selection and characteristics

Figure 1 shows the PRISMA flowchart. Eighty-four studies were included, comprising 12 systematic reviews (15%), 54 randomized controlled trials (64%) and 18 non-randomized comparative or controlled cross-over studies (21%). Based on the risk of bias assessment, nine of the studies were deemed to be of high quality (11%), 20 were of moderate quality (24%) and 55 were of low quality (65%), often due to small sample sizes. Further details about each study are available in the online supplement (Tables E1, E2, E3, E4).

Managing acute reactions

Table 1 lists the key findings.

People with food allergy are often advised to completely avoid allergenic foods, but this may not always be possible. Pharmacological treatments are available to help people manage the symptoms when they are exposed to food allergens. The most common class of drugs assessed for this purpose is H1-antihistamines, taken as required when symptoms occur.

Three randomized trials and two non-randomized comparisons, all with methodological issues, suggested that H1-antihistamines may have some benefit, particularly in combination with other drugs (8-12). Some of the literature about H1-antihistamines focused on treating those with a primary birch pollen allergy and cross-reactive symptoms with biological related foods (pollen-food syndrome), while other studies included people with a diverse range of disease manifestations. The safety profile of H1-antihistamines in people with food allergy was not well reported.

Other medications have been used in people with food allergy, but we failed to identify any studies investigating these medicines that fulfilled the inclusion criteria.
### Table 1  Summary of key findings

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Studies</th>
<th>% High quality</th>
<th>Overall findings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STRATEGIES TO TREAT ACUTE SYMPTOMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antihistamines</td>
<td>5</td>
<td>0%</td>
<td>Three randomized trials and two non-randomized comparisons found that antihistamines may reduce immediate symptoms or severity in children and adults (8-12).</td>
</tr>
<tr>
<td><strong>LONG-TERM MANAGEMENT STRATEGIES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antihistamines</td>
<td>1</td>
<td>0%</td>
<td>One trial found prophylactic antihistamines improved symptoms (22).</td>
</tr>
<tr>
<td>Mast cell stabilizers</td>
<td>9</td>
<td>0%</td>
<td>Four randomized trials and two non-randomized comparisons found that prophylactic mast cell stabilizers reduced symptoms or severity in children, adults or both (13-18). Three randomized trials found no benefits. Side effects were noted (19-21).</td>
</tr>
<tr>
<td>Other pharmacological treatments</td>
<td>2</td>
<td>0%</td>
<td>One trial of calf thymus acid lysate derivative found improved skin lesions (23). One trial of a herbal treatment found no improvement in symptoms (24).</td>
</tr>
<tr>
<td>Dietary elimination</td>
<td>4</td>
<td>0%</td>
<td>One trial and one non-randomized comparison found that dietary elimination worked well for children allergic to cows’ milk or eggs, (41, 42) but a systematic review and a non-randomized comparison suggested no benefits for spices or fruit allergies in children (43, 44). No relevant studies were identified in adults.</td>
</tr>
<tr>
<td>Dietary substitution: cows’ milk formula substitutes</td>
<td>17</td>
<td>12%</td>
<td>One trial and one non-randomized comparison found extensively hydrolyzed formulas to be well tolerated (25, 26). A systematic review and three randomized trials found that amino acid-based formulas were well tolerated and may reduce symptoms among infants with cows’ milk allergy (27-30). A systematic review and a randomized controlled trial concluded that soy milk is nutritionally adequate and well tolerated, (31, 32) but a randomized trial concluded that soy may be less well tolerated than extensively hydrolyzed whey formula (33). Two randomized controlled trials found that rice hydrolyzate formula was well tolerated, (34, 35) but one randomized trial found no benefits (36). One randomized trial found that almond milk was well tolerated (37). Another randomized trial found that chicken-based formula was better tolerated than soy-based formula (38). A systematic review concluded that donkey or mare’s milk was as allergenic as cows’ milk, (31) but a randomized trial suggested that donkey’s milk was better tolerated than goat’s milk (39). A non-random comparison found that meat-based formulas were well tolerated and reduced symptoms in infants with other food allergies (40).</td>
</tr>
<tr>
<td>Probiotic supplements</td>
<td>11</td>
<td>27%</td>
<td>One systematic review, three randomized trials and one non-randomized comparison found that probiotic supplements may reduce symptoms and support long-term tolerance in infants with cows’ milk allergy or other allergies (45-49). Five randomized trials found no benefits in infants and one trial found no benefits in young adults (50-55).</td>
</tr>
<tr>
<td>Subcutaneous immunotherapy</td>
<td>9</td>
<td>11%</td>
<td>Five randomized trials and four other studies found improved tolerability in children and adults (56-63). One trial found no benefits (64).</td>
</tr>
<tr>
<td>Sublingual immunotherapy</td>
<td>5</td>
<td>0%</td>
<td>Four trials found that sublingual immunotherapy was associated with improved tolerability for those with peanut and fruit allergies (65-68). One trial found no benefit (69).</td>
</tr>
<tr>
<td>Oral immunotherapy</td>
<td>18</td>
<td>22%</td>
<td>Two systematic reviews, nine randomized trials and four non-randomized comparisons found that oral immunotherapy was associated with improved tolerability for children and adults with various food allergies (70-83). One randomized trial found no benefit (84). Two systematic reviews found mixed evidence and concluded that oral immunotherapy should not be routine treatment (85, 86).</td>
</tr>
</tbody>
</table>
Longer-term management

Pharmacological treatment

Pharmacological strategies for long-term management involve taking ongoing treatment to prevent symptoms from reappearing or worsening (as well as potentially treating existing manifestations).

There were mixed findings about mast cell stabilizers used prophylactically for food allergy symptoms. Four randomized trials and two non-randomized comparisons found that mast cell stabilizers reduced symptoms or severity in children, adults, or both (13-18). Three randomized trials found no benefits (19-21). Side-effects were noted, but were usually not severe.

There was insufficient evidence upon which to base recommendations about other pharmacological treatments. One randomized trial found that H1-antihistamines could have a prophylactic effect (22) and one trial of calf thymus acid lysate derivative found improvement in skin lesions (23). A trial of a herbal treatment was not effective (24).

Dietary interventions

More research was available about dietary interventions. For instance, a number of studies investigated alternatives to cow’s milk formula for infants with cow’s milk allergy. Here the evidence base was moderate. Although in common use, cow’s milk hydrolyzates were not rigorously compared to standard cow’s milk formula alone. Instead, extensively hydrolyzed cow’s milk formulas were often used as a comparator in studies of other alternatives such as soy or amino acid-based formulas.

There was some evidence to suggest that extensively hydrolyzed cow’s milk formula and amino acid-based formula may be useful long-term management strategies for infants with cow’s milk allergy of which extensively hydrolysed formulas are the first choice. For example, one randomized trial and one non-randomized comparison found that extensively hydrolyzed cow’s milk formulas were well tolerated (25, 26). One systematic review and three randomized trials found that amino acid-based formulas were well tolerated and may reduce symptoms among infants with cow’s milk allergy (27-30). The research suggested that amino acid-based formulas may be as effective, or more effective, than extensively hydrolyzed whey formula.

Another systematic review and a randomized controlled trial concluded that soy milk was nutritionally adequate and well tolerated in children allergic to cow’s milk (31, 32), but a randomized trial found that soy may be less well tolerated than extensively hydrolyzed whey formula, especially among infants younger than six months (33). Two randomized controlled trials suggested that rice hydrolyzate formula was well tolerated among infants with cow’s milk allergy and may even reduce the duration of allergy (34, 35). However, another randomized trial found no improvements (36). There was less evidence about other alternatives to cow’s milk. One randomized trial found that almond milk was well tolerated (37). Another randomized trial found that chicken-based formula was better tolerated than soy-based formula (38).

A systematic review concluded that donkey or mare’s milk were as allergenic as cow’s milk (31), but a randomized trial suggested that donkey’s milk was better tolerated than goat’s milk and reduced symptoms in infants with cow’s milk allergy (39).

Our review identified no high-quality studies about other alternatives such as camel’s milk or oat milk.

In infants with allergies to food other than cow’s milk, a non-random comparison found that meat-based formulas were well tolerated and reduced symptoms (40).

Another key strategy in the long-term management of food allergy involved eliminating the offending food from the diet. Apart from the studies above about eliminating cow’s milk for infants, this intervention has received relatively little research attention, perhaps because it is deemed ‘common sense’ that avoidance will reduce symptoms. One randomized trial and one non-randomized comparison found that eliminating the foods that children were allergic to from the diet was associated with remission of symptoms and reduced reactions to allergens over time (41, 42). This worked well for children allergic to cow’s milk or hen’s eggs. However a review and a non-randomized comparison suggested dietary elimination may be more difficult for spices (43) or fruit allergies (44). No relevant studies were identified solely focusing on adults.

Dietary supplements

Evidence about the effectiveness of using probiotic supplements as a way to minimize food allergy was mixed. A systematic review, three randomized controlled trials and one non-randomized comparison
found that probiotic supplements may reduce symptoms and support long-term tolerance in infants with cow’s milk allergy or other allergies (45-49). However, five randomized trials found no benefits in infants and one trial found no benefits in young adults (50-55). Some of the studies found that probiotics were more effective in IgE-mediated food allergy.

The review identified no studies meeting the inclusion criteria that focused on prebiotics or other supplements for the long-term management of food allergy.

**Allergen-specific immunotherapy**

The greatest amount of research focused on different forms of immunotherapy, either with food extracts or cross-reactive pollen extract. Studies generally found that subcutaneous immunotherapy with food extract was associated with improved tolerance and reduced symptoms in children and adults with various food allergies (56, 57). The same was true with cross-reactive pollen extract, (58-61) and other extracts (62). However, the amount of food tolerated remained small and side effects were common. One randomized trial found no benefit (63).

Another option is sublingual immunotherapy, where allergen extracts are placed under the tongue to promote desensitization. Four randomized trials found that sublingual immunotherapy with food extracts was associated with improved tolerance and reduced symptoms for those with peanut, hazelnut and peach allergies (64-67). The treatment was generally well tolerated, with few suffering adverse reactions. One randomized trial with cross-reactive pollen extract found no benefit (68).

Two systematic reviews, nine randomized trials and four non-randomized comparisons found that oral immunotherapy (or specific oral tolerance induction; SOTI) was associated with improved tolerance and reduced symptoms for children and adults with various food allergies (69-82). Around half of participants suffered side effects, though these were not usually severe. One randomized trial found no benefit (83). One systematic review of oral immunotherapy found mixed evidence and suggested that this should not be recommended as routine treatment (84).

Immunotherapy is currently only a research intervention, but may be promising therapeutically. As with all of other interventions considered in this review, however, the evidence base was overall of low quality. Another issue is that most immunotherapy studies did not explore what happens once the relatively short-term treatment phase ceases. Whereas most studies of dietary interventions and probiotic supplements have focused on children, the majority of research into injection immunotherapy for food allergy has targeted adults. Studies of oral ingestion have included both children and adults.

There were no high-quality studies identified about other long-term management strategies such as educational or behavioral interventions. Nor did any studies about cost-effectiveness meet the inclusion criteria.

**Discussion**

**Statement of principal findings**

This is one of the most comprehensive systematic reviews about the management of food allergy ever undertaken. There was a substantial body of experimental evidence uncovered. However, much of it comprises small-scale, relatively low-grade studies. Nonetheless, there was some evidence that H1-antihistamines can be effective in improving acute cutaneous manifestations of food allergy.

Regarding longer-term management, avoiding or substituting food was a common approach. There was evidence that cow’s milk substitutes can be particularly beneficial for cow’s milk allergy. There was no evidence to recommend probiotic supplements to improve outcomes in children or adults with food allergy.

A large quantity of research has been undertaken about different forms of immunotherapy. Although immunotherapy is not currently used in routine practice, the preliminary data were encouraging and further study is warranted. It is important to balance the benefits with the risks of immunotherapy, and further investigation is required to explore any subgroups that may benefit most. It is uncertain whether any gains in tolerance will continue while on treatment or when treatment ceases. Where studies did examine this, tolerance tended to persist only for a few months after immunotherapy ceased.

**Strengths and limitations**

This review included the most up-to-date research about both the acute and long-term management of food allergy, with studies from Europe, North America, Asia and Australasia. It was conducted using stringent...
international standards and drew on a substantially greater evidence base than previous reviews on this subject (85, 86).

However, the studies included were heterogeneous, meaning that meta-analysis was not possible. The inclusion criteria meant that studies about educational, behavioral and psychological interventions were omitted as these tended to be investigated using uncontrolled before-and-after designs or lower quality methods. Safety was assessed only in some studies. Further trials using standardized measures of side effects are required to assess the risks associated with different treatments. Furthermore, the review was unable to quantify overall treatment effects, draw conclusions about the comparative effectiveness of different management approaches or the population sub-groups that may benefit most.

Conclusions
Food allergy is complex because the best management strategy is likely to depend on exactly what the person is allergic to, the ways this manifests, the types of treatments they have tried in the past and their responses to those treatments.

There is weak evidence to recommend H1-antihistamines to alleviate immediate, non-life threatening symptoms in children and adults with food allergy. There is also weak evidence to recommend mast cell stabilizer drugs for the prophylactic treatment of symptoms in some children or adults with food allergy. There is moderate evidence to recommend alternatives to cow’s milk formula for infants with cow’s milk allergy. Extensively hydrolyzed whey formula and amino acid-based formula have been found to have benefits, with less evidence for soy and rice hydrolyzate. There is no evidence for other foods or for how foods should be re-introduced to the diet.

There is more encouraging evidence to support further exploration of immunotherapy, although the quality of the evidence base is questionable and the treatment is often associated with adverse effects. Further research could usefully explore whether the benefits of treatment continue after the intervention is stopped, as this is an area where there are limited data.

Overall, the review suggests that there is an urgent need to better understand how to support the millions of people who suffer from food allergy.

Acknowledgements
We would like to acknowledge the support of EAACI and the EAACI Food Allergy and Anaphylaxis Guidelines Group in developing this systematic review. We would also like to thank the EAACI Executive Committee for their suggestions.

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EAACI

Contributorship
AS, AM, DdS and GR conceived this review. The review was undertaken by DdS, MG and colleagues at The Evidence Centre. DdS led the drafting of the manuscript and all authors commented on drafts of the manuscript and agreed the final version. This review was undertaken as part of a series managed by SSP and overseen by AS.

Conflicts of interest
None known

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Managing food allergy: systematic review


1.5

DIAGNOSIS AND MANAGEMENT OF FOOD ALLERGY

EAACI GUIDELINES

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* Joint first author
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Food allergy can result in considerable morbidity, impact negatively on quality of life and prove costly in terms of medical care. These guidelines have been prepared by the European Academy of Allergy and Clinical Immunology’s (EAACI) Food Allergy and Anaphylaxis Guidelines Group, building on previous EAACI position papers on adverse reaction to foods and three recent systematic reviews on the epidemiology, diagnosis and management of food allergy and provide evidence-based recommendations for the diagnosis and management of food allergy. While the primary audience is allergists, this document is relevant for all other healthcare professionals including primary care physicians, and paediatric and adult specialists, dieticians, pharmacists and paramedics. Our current understanding of the manifestations of food allergy, the role of diagnostic tests and the effective management of patients of all ages with food allergy is presented. The acute management of non-life threatening reactions is covered in these guidelines, but for guidance on the emergency management of anaphylaxis, readers are referred to the related EAACI anaphylaxis guidelines.

**BACKGROUND**

Food allergy has been defined as adverse reactions to food in which “immunologic mechanisms have been demonstrated” (1, 2); this term therefore encompasses both immunoglobulin E (IgE)-mediated and non-IgE-mediated food allergies (Tables 1, 2). Food allergy can result in considerable morbidity and in some instances results in life-threatening anaphylaxis. These guidelines aim to provide evidence-based recommendations for the diagnosis and management of patients of any age with suspected or confirmed food allergy. Development of the guidelines has been based on three systematic reviews of the epidemiology (Chapters 1.1, 1.2), diagnosis (Chapter 1.3) and management (Chapter 1.4) of food allergy with weaker forms of evidence being used where there were insufficient data from more robust studies or where high level evidence is practically or ethically unobtainable. These guidelines build on the previous EAACI position paper on adverse reaction to foods (3) and are complementary to the other current food allergy guidelines, including the United States (US) National Institute of Allergy and Infectious Diseases (NIAID) guidelines (4). Distinctive features include a European focus and the placing of particular emphasis on the practical issues associated with diagnosis and long-term management of food allergy.

**Table 1** Key Terms (2)

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Allergen</strong></td>
<td>Any substance stimulating the production of immunoglobulin IgE or a cellular immune response; usually a protein.</td>
</tr>
<tr>
<td><strong>Atopic eczema/dermatitis</strong></td>
<td>Chronic inflammatory skin disease characterized by typical age related lesions with pruritus and personal or family history of atopic disease.</td>
</tr>
<tr>
<td><strong>Co-factors</strong></td>
<td>Patient related external circumstances that are associated with more severe allergic reactions. They are also known as augmentation factors.</td>
</tr>
<tr>
<td><strong>Eosinophilic esophagitis</strong></td>
<td>A chronic, immune/antigen-mediated esophageal disease characterized clinically by symptoms related to esophageal dysfunction and histologically by eosinophil-predominant inflammation.</td>
</tr>
<tr>
<td><strong>Food</strong></td>
<td>Any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of “food” but does not include cosmetics or tobacco or substances used only as drugs (Codex Alimentarius).</td>
</tr>
<tr>
<td><strong>Food allergy</strong></td>
<td>An adverse reaction to food mediated by an immunological mechanism, involving specific IgE (IgE mediated), cell–mediated mechanisms (non IgE mediated) or both IgE and cell mediated mechanisms (mixed IgE and non IgE mediated).</td>
</tr>
<tr>
<td><strong>Food desensitization</strong></td>
<td>Induction of short-term tolerance that may disappear after withdrawal of the treatment.</td>
</tr>
<tr>
<td><strong>Oral tolerance</strong></td>
<td>A state of local and systemic immune unresponsiveness induced by oral administration of innocuous antigens / allergens.</td>
</tr>
<tr>
<td><strong>Oligo-allergenic diet</strong></td>
<td>An empirical elimination diet with minimal content of major food allergens for the given population.</td>
</tr>
<tr>
<td><strong>Oral tolerance induction</strong></td>
<td>A state of local and systemic permanent immune unresponsiveness induced by following oral administration consumption of innocuous antigens such as food proteins; does not disappear after withdrawal of the antigens.</td>
</tr>
<tr>
<td><strong>Prebiotic</strong></td>
<td>Non-digestible substances that provide a beneficial physiological effect for the host by selectively stimulating the favourable growth or activity of a limited number of indigenous bacteria.</td>
</tr>
<tr>
<td><strong>Probiotic</strong></td>
<td>Live microorganisms which, when administered in adequate amounts, confer a health benefit on the host.</td>
</tr>
<tr>
<td><strong>Sensitization</strong></td>
<td>Presence of specific IgE to an allergen.</td>
</tr>
<tr>
<td><strong>Symbiotics</strong></td>
<td>A mixture of probiotics and prebiotics.</td>
</tr>
</tbody>
</table>
## Table 2  Food-induced allergic disorders (classified based on the underlying immunopathology)

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Clinical features</th>
<th>Typical age group</th>
<th>Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IgE MEDIATED</strong></td>
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<tr>
<td>Pollen food allergy syndrome</td>
<td>Pruritus, mild edema confined to oral cavity</td>
<td>Onset after pollen allergy established (adult &gt; young child)</td>
<td>May be persistent and may vary by season</td>
</tr>
<tr>
<td>Urticaria/angioedema</td>
<td>Triggered by ingestion or direct contact</td>
<td>Children &gt; adults</td>
<td>Depends on food</td>
</tr>
<tr>
<td>Rhinconjunctivitis/asthma</td>
<td>Accompanies food-induced allergic reaction but rarely isolated symptoms</td>
<td>Infants/child &gt; adult, except for occupational disease</td>
<td>Depends on food</td>
</tr>
<tr>
<td>Gastrointestinal symptoms</td>
<td>Symptoms such as nausea, emesis, abdominal pain and diarrhea triggered by food ingestion</td>
<td>Any age</td>
<td>Depends on food</td>
</tr>
<tr>
<td>Anaphylaxis</td>
<td>Rapid progressive, multisystem reaction</td>
<td>Any age</td>
<td>Depends on food</td>
</tr>
<tr>
<td>Food-dependent, exercise-induced anaphylaxis</td>
<td>Food triggers anaphylaxis only if ingestion is followed temporally by exercise</td>
<td>Onset in late childhood/adulthood</td>
<td>Presumed persistent</td>
</tr>
<tr>
<td><strong>MIXED IgE AND CELL MEDIATED</strong></td>
<td></td>
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</tr>
<tr>
<td>Atopic eczema/dermatitis</td>
<td>Associated with food in 30%-40% of children with moderate/severe eczema</td>
<td>Infant &gt; child &gt; adult</td>
<td>Usually resolves</td>
</tr>
<tr>
<td>Eosinophilic gastrointestinal disorders</td>
<td>Symptoms vary depending on the site of the intestinal tract involved and degree of eosinophilic inflammation</td>
<td>Any age</td>
<td>Likely persistent</td>
</tr>
<tr>
<td><strong>CELL MEDIATED</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Dietary protein-induced proctitis/proctocolitis</td>
<td>Mucus-laden, bloody stools in infants</td>
<td>Infancy</td>
<td>Usually resolves</td>
</tr>
<tr>
<td>Food protein-induced enterocolitis syndrome</td>
<td>Chronic exposure: emesis, diarrhea, poor growth, lethargy Re-exposure after restriction: emesis, diarrhea, hypotension a couple of hour after ingestion</td>
<td>Infancy</td>
<td>Usually resolves</td>
</tr>
</tbody>
</table>

Modified from Sicherer and Sampson (16)

## METHODS

These guidelines were produced using the Appraisal of Guidelines for Research & Evaluation (AGREE II) approach (5, 6). This is a structured approach for the production of guidelines designed to ensure appropriate representation of the full range of stakeholders, a careful search and appraisal of the relevant literature and a systematic approach to the formulation and presentation of recommendations. In order to ensure that the risk of bias is minimized at each step of the process, interim consensus meetings were organised. An overview of the approach is provided below.

### Clarifying the scope and purpose of the guidelines

The scope of these EAACI guidelines is multifaceted providing statements that assist clinicians in the management of food allergy in daily practice; harmonizing the approach to this disease among stakeholders across Europe; and advocating for further research.
Ensuring appropriate stakeholder involvement

Participants and experts in the Food Allergy Diagnosis and Management Taskforce represented a range of 12 European countries and disciplinary and clinical backgrounds (gastroenterologists A Schoepfer, A Staiano, R Troncone; primary care A Sheikh; dietitians C Venter, I Skypa BJ Vlieg-Boerstra, M Groetch) and patient groups (MJ Marchisotto -FARE).

Systematic reviews of the evidence

The initial full range of questions that were considered important were rationalized through several rounds of iteration into three key questions that were then pursued through two formal systematic reviews of the evidence (7-9) (see Box 1).

Formulating recommendations

We graded the strength and consistency of key findings from these systematic reviews to formulate evidence-linked recommendations for care (10) (Box 2). This involved formulation of clear recommendations and the strength of evidence underpinning each recommendation. Experts identified barriers and facilitators to the implementation of each recommendation and included advice how to implement and listed audit criteria that may facilitate organizational compliance.

Box 1 Key questions addressed in the supporting systematic reviews: diagnosis and management (7-9)

- What is the epidemiology (i.e. frequency, risk factors and outcomes) of food allergy in Europe and how does this vary by time, place and person?
- What is the diagnostic accuracy of tests aimed at supporting the clinical diagnosis of food allergy?
- What is the effectiveness of pharmacological and non-pharmacological interventions for the management of acute, non-life-threatening food allergic reactions?
- What is the effectiveness of pharmacological and non-pharmacological interventions for the longer-term management of food allergy?

Peer review and public comment

A draft of these guidelines was externally peer-reviewed by invited experts from a range of organizations, countries and professional backgrounds. Additionally, the draft guidelines were made available on the EAACI website for a 3 week period (June 2013) to allow all stakeholders to comment. All feedback was considered by the Food Allergy Diagnosis and Management Taskforce and, where appropriate, revisions were made.

Identification of evidence gaps

The process of developing these guidelines has identified a number of evidence gaps and it is planned to formally prioritize these in the future. We plan to draft outline research briefs that funders can use to commission research on these questions.

Editorial independence and managing conflict of interests

The production of these guidelines was funded and supported by EAACI. The funders did not have any influence on the guidelines production process, its contents or on the decision to publish. Taskforce members’ conflicts of interest were taken into account by the Taskforce chair as recommendations were formulated.

Updating the guidelines

We plan to update these guidelines in 2017 unless there are important advances before then.

Epidemiology

To estimate the incidence and prevalence, time-trends, and potential risk and prognostic factors for food allergy in Europe, we conducted a systematic review of recent (i.e. 2000-2012) European studies (7) (Chapters 1.1, 1.2). One hundred and nine articles were assessed for eligibility and 75 (comprising of 56 primary studies) were included in a narrative synthesis and 30 studies in a meta-analysis. Most of the studies were graded as at moderate risk of bias. A summary of the key findings is presented in Table 3. The point prevalence of self-reported food allergy was approximately six times higher than the point prevalence of challenge proven food allergy. The prevalence of food allergy was generally higher in
Box 2 Assigning levels of evidence and recommendations according to new grading system (11,12)

<table>
<thead>
<tr>
<th>LEVEL OF EVIDENCE FOR ESTABLISHING DIAGNOSTIC TEST ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I: A systematic review of level II studies</td>
</tr>
<tr>
<td>Level II: A study of test accuracy with: an independent, blinded comparison with a valid reference standard, among consecutive persons with a defined clinical presentation</td>
</tr>
<tr>
<td>Level III-1*: A study of test accuracy with: an independent, blinded comparison with a valid reference standard, among non-consecutive persons with a defined clinical presentation</td>
</tr>
<tr>
<td>Level III-2*: A comparison with reference standard that does not meet the criteria required for level II and III-1 evidence</td>
</tr>
<tr>
<td>Level III-3*: Diagnostic case-control study</td>
</tr>
<tr>
<td>Level IV: Study of diagnostic yield (no reference standard)</td>
</tr>
<tr>
<td>Level V: Case reports and expert opinion that include narrative literature, reviews and consensus statements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LEVEL OF EVIDENCE FOR ASSESSING EFFECTIVENESS OF INTERVENTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I: Systematic reviews, meta-analysis, randomized control trials</td>
</tr>
<tr>
<td>Level II: Two groups, non-randomized studies (e.g. cohort, case-control)</td>
</tr>
<tr>
<td>Level III: One-group non-randomized (e.g. before and after, pre-test and post-test)</td>
</tr>
<tr>
<td>Level IV: Descriptive studies that include analysis of outcomes (single-subject design, case-series)</td>
</tr>
<tr>
<td>Level V: Case reports and expert opinion that include narrative literature, reviews and consensus statements</td>
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</tbody>
</table>

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<tr>
<th>GRADES OF RECOMMENDATION</th>
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<tbody>
<tr>
<td>Grade A: Consistent level I studies</td>
</tr>
<tr>
<td>Grade B: Consistent level II or III studies or extrapolations from level I studies</td>
</tr>
<tr>
<td>Grade C: Level IV studies or extrapolations from level II or III studies</td>
</tr>
<tr>
<td>Grade D: Level V evidence or troublingly inconsistent or inconclusive studies at any level</td>
</tr>
</tbody>
</table>

* For consistency with the anaphylaxis guidelines (Chapter 4.3), level III-1 to level III-3 for establishing diagnostic test accuracy are summarised as level III in this document.

children than in adults. While the prevalence of primary food allergy appeared to be stable over time, the prevalence of secondary food allergy caused by cross-reactions of food allergens with inhalant allergens appears to be increasing. There were no consistent risk or prognostic factors for the development or resolution of food allergy. However, sex, age, country of residence, familial atopic history, and the presence of other allergic diseases may play an important role in its etiology.

Few studies employed double-blind, placebo-controlled food challenge (DBPCFC) in a population-based sample; further studies are therefore required to establish the actual prevalence of objectively-confirmed food allergy in the general population. Further studies are also needed to investigate the long-term prognosis of food allergy.
Table 3  Summary of the pooled prevalence of food allergy (FA) in Europe, by age and region: studies published 1 January 2000 – 30 September 2012

<table>
<thead>
<tr>
<th></th>
<th>Self-reported food allergy</th>
<th>Sensitization to at least one food allergen (point prevalence)</th>
<th>Symptoms + sensitization to at least one food allergen (point prevalence)</th>
<th>Convincing clinical history or positive food challenge or DBPCFC (point prevalence)</th>
<th>Positive open food challenge or DBPCFC (point prevalence)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(life time prevalence)</td>
<td>(point prevalence)</td>
<td></td>
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<tr>
<td>All</td>
<td>17.3 (17.0-17.6)</td>
<td>5.9 (5.7-6.1)</td>
<td>10.7 (9.4-10.8)</td>
<td>3.0 (2.7-3.3)</td>
<td>2.7 (1.7-3.7)</td>
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<td>1.5 (1.3-1.7)</td>
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<td>2.6 (2.1-3.1)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.9 (0.8-1.1)</td>
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<tr>
<td><strong>AGE</strong></td>
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<tr>
<td>Children (0-17 years)</td>
<td>17.4 (16.9-18.0)</td>
<td>6.9 (6.6-7.2)</td>
<td>12.2 (11.4-13.1)</td>
<td>3.0 (2.7-3.3)</td>
<td>3.6 (2.8-4.4)</td>
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<td>1.5 (1.3-1.7)</td>
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<td>2.6 (2.1-3.1)</td>
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<td></td>
<td></td>
<td>1.0 (0.8-1.2)</td>
</tr>
<tr>
<td>Adults (≥ 18 years)</td>
<td>17.2 (16.0-17.6)</td>
<td>5.1 (4.8-5.3)</td>
<td>4.1 (3.2-5.1)</td>
<td>6</td>
<td>2.2 (0.8-3.7)</td>
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<td>0.9 (0.8-1.0)</td>
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<tr>
<td><strong>REGION</strong></td>
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</tr>
<tr>
<td>Western Europe</td>
<td>23.8 (22.9-24.7)</td>
<td>3.3 (3.1-3.5)</td>
<td>11.7 (9.8-13.6)</td>
<td>1.8 (1.5-2.1)</td>
<td>2.6 (1.3-3.8)</td>
</tr>
<tr>
<td></td>
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<td>1.4 (1.1-1.7)</td>
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<td></td>
<td></td>
<td>3.1 (2.6-3.7)</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>41.6 (39.5-43.7)</td>
<td>3.3 (1.2-5.4)</td>
<td>— (6)</td>
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<td>— (6)</td>
</tr>
<tr>
<td>Southern Europe</td>
<td>8.6 (8.2-9.0)</td>
<td>3.5 (2.5-4.5)</td>
<td>— (6)</td>
<td>— (6)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.2 (0.1-0.3)</td>
</tr>
<tr>
<td>Northern Europe</td>
<td>30.3 (28.7-31.9)</td>
<td>14.5 (13.9-15.2)</td>
<td>9.8 (9.0-10.5)</td>
<td>5.4 (4.6-6.1)</td>
<td>3.0 (2.1-3.9)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>1.6 (0.9-2.3)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.6 (2.1-3.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.1 (0.9-1.3)</td>
</tr>
<tr>
<td>Europe</td>
<td>19.2 (18.6-19.8)</td>
<td>5.0 (4.6-5.5)</td>
<td>— (6)</td>
<td>— (6)</td>
<td>— (6)</td>
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<td>— (6)</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>— (6)</td>
</tr>
</tbody>
</table>

Figures are percentages (95% CI).

1 The pooled prevalence of FA was based on random-effects meta-analysis for 30 clinically and methodologically comparable studies.
2 Where a study reported estimates for both open food challenges and DBPCFC, the DBPCFC estimates were always used; otherwise open food challenges estimates were used if DBPCFC was not done in the study.
3 European region were classified based on the United Nations classification (http://unstats.un.org/unsd/methods/m49/m49regin.htm#europe accessed on December 28, 2012).
4 We further added studies from Turkey into Southern Europe.
5 For studies that included several European countries and gave overall estimate for all the countries and in which it was not possible to calculate the frequency for each country studied.
6 No study undertaken for this group for this particular outcome.
# Box 3  EAACI Recommendation on the diagnosis of food allergy

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A - PATIENT'S CLINICAL HISTORY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detailed clinical history is essential for the diagnosis of food allergy.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>When taking a clinical history eliciting allergens, timing and chronicity, symptoms, severity and signs, reproducibility, known risk (co) factors, family history, co-existing medical problems including other allergic diseases should be addressed.</td>
<td>V</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>The use of structured questions on symptoms, foods and other background information is recommended.</td>
<td>V</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td><strong>B - DETERMINATION OF SENSITIZATION TO FOOD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where available, standardized tests and procedures should be used.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>IgE sensitization does not always predict clinical relevant food allergy, so specific allergy testing should be directed by case history.</td>
<td>IV</td>
<td>C</td>
<td>(9)</td>
</tr>
<tr>
<td>Either SPT or sIgE can be the test of choice for sensitization depending on local availability and absolute and relative contraindications to SPT.</td>
<td>IV</td>
<td>C</td>
<td>(9)</td>
</tr>
<tr>
<td>Evidence of IgE sensitization to common food and appropriate aeroallergens can support a diagnosis of food allergy in conjunction with clinical history and/or food challenge.</td>
<td>I-III*</td>
<td>A-C</td>
<td>(9)</td>
</tr>
<tr>
<td>In the presence of a suggestive history, a negative SPT or sIgE needs to be interpreted with caution particularly as these are expected in non-IgE mediated food allergy.</td>
<td>IV</td>
<td>C</td>
<td>(9)</td>
</tr>
<tr>
<td>Where SPT and sIgE tests are inconclusive, CRD (if available) may provide additional diagnostic information.</td>
<td>I – IV*</td>
<td>A – C*</td>
<td>(9, 28-30)</td>
</tr>
<tr>
<td>If clinical history with SPT and/or sIgE results is not highly predictive (see Figure 1), an OFC is required.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>Determination of total IgE is particularly useful in patients with severe eczema; a very high total IgE level suggests that positive specific IgE results should be interpreted with care as they may represent asymptomatic sensitization.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td><strong>C - ELIMINATION DIETS FOR DIAGNOSTIC PURPOSES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determining which foods to be avoided should be based on the allergy-focused diet history, clinical history and allergy testing (SPTs and/or sIgE).</td>
<td>V</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>For each individually avoided food, the results of the diagnostic elimination diet should be carefully monitored and evaluated over 2-4 weeks of avoidance.</td>
<td>V</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>Where the elimination diet leads to a significant relief of symptoms, it should be continued until the provocation test is performed.</td>
<td>V</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>Where the elimination diet does not lead to a significant relief of symptoms, food allergy to the eliminated foods is highly unlikely.</td>
<td>V</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
</tbody>
</table>
**Box 3 (continued)**

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D - ORAL FOOD CHALLENGE (OFC)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The OFC (particularly the double-blind placebo-controlled food challenge) is the gold standard investigation for the objective diagnosis of IgE-and non-IgE mediated food allergy.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>OFC’s should be used to demonstrate allergy or tolerance and in so doing facilitate safe dietary expansion or appropriate allergen avoidance.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>The DBPCFC should be performed when symptoms are subjective, with delayed or atypical symptoms, where patients and/or care givers are anxious, and considered in all research settings.</td>
<td>IV</td>
<td>D</td>
<td>(24, 26)</td>
</tr>
<tr>
<td>A negative DBPCFC should end with an open or cumulative ingestion of the food based on a normal age appropriate portion to confirm oral tolerance.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>OFC must be performed in a specialist setting with emergency support immediately available; where there is a moderate to high risk of a severe reaction, intensive care support must be immediately available.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td><strong>E - DIAGNOSIS OF EOE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every patient with EoE should be referred to an allergist/immunologist for workup.</td>
<td>IV</td>
<td>D</td>
<td>(47)</td>
</tr>
<tr>
<td>EoE is diagnosed by an upper endoscopy with 2-4 biopsies from both the proximal and distal esophageal biopsies. Biopsies should be performed when the patient has been treated for at least 6 weeks with double dose proton pump inhibitors to rule out esophageal eosinophilia caused by gastro-esophageal reflux disease (GERD) and to exclude proton-pump inhibitor responsive esophageal eosinophilia.</td>
<td>IV</td>
<td>D</td>
<td>(47, 48)</td>
</tr>
<tr>
<td>The clinical utility of measuring serum food-specific IgE and skin prick test results to generate a successful elimination diet needs further investigation. Future studies should clearly document a clinical and histologic benefit from dietary interventions guided by results from serum-IgE levels, skin prick testing or atopy patch testing.</td>
<td>IV</td>
<td>D</td>
<td>(47)</td>
</tr>
<tr>
<td><strong>F - UNCONVENTIONAL TESTS, INCLUDING SPECIFIC IgG TESTING</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There are no unconventional tests which can be recommended as an alternative or complementary diagnostic tool in the work up of suspected food allergy, and their use should be discouraged.</td>
<td>III</td>
<td>C</td>
<td>(54)</td>
</tr>
</tbody>
</table>

*Range of levels of evidence and grades are due to range of different foods tested.
DIAGNOSIS

Patient’s clinical history and examination

The clinical presentation of food allergy involves a large spectrum of symptoms ranging from skin (urticaria, angioedema, atopic eczema/dermatitis), gastrointestinal (i.e. vomiting, colic, abdominal pain, diarrhoea, constipation), respiratory (rhinorrhea, sneezing, cough, dyspnea) to circulatory (cardiovascular collapse). Attention should be paid to the fact, that reactions can be triggered by food ingestion, inhalation and skin contact. A careful dietary history is fundamental to the diagnosis of food allergy (see Appendix I-A and I-B). It can establish the likelihood of the diagnosis, suggest whether an IgE- or non-IgE mechanism is involved and identify the potential food triggers. A small amount of literature indicates that the predictive value of the clinical history for immediate symptoms, either alone or in combination with skin prick tests (SPT) or serum specific-IgE (sIgE) blood tests, ranges from 50-00% (13-15). The clinical evaluation should include a thorough examination of nutritional status and growth, especially in children, as well as associated atopic diseases such as atopic eczema/dermatitis, allergic rhinitis and asthma.

Recommendations Box 3-A

Diagnostic tests for food allergy

In vivo SPT and sIgE for food allergens are the first line tests to assess IgE sensitization. However, like the patient history, these tests cannot always accurately diagnose food allergy. Elimination diet for diagnostic purposes and oral food challenges are still required both for IgE and non-IgE mediated food allergy in order to define the clinical relevance of the initial investigations. For some clinical manifestations such as food-induced enteropathies, endoscopy and biopsy are often required to establish the diagnosis. The diagnostic workup of food allergy is summarized in Figure 1.

Figure 1 Algorithm for the diagnosis of food allergy
Specific IgE: In-vitro and skin tests

The determination of sensitization to suspected food allergens includes the assessment of co- and cross-sensitization to related food or aeroallergens. To avoid identifying food allergens where sensitization is seen without clinical relevance, only food and aeroallergens related to the clinical presentation, age, geographic location and ethnic dietary habits of the patient should be investigated.

Specific IgE and SPT are scientifically valid tests although not all are standardized. Currently single recombinant protein solutions for SPT are not approved in the EU. However, in some countries purified natural date profilin and Pru p 3 are available for SPT. Determination of total IgE levels can be helpful in the interpretation of results as very high IgE levels can be associated with multiple positive SPTs or sIgE results that are not clinically relevant.

SPT can be undertaken in patients of any age although reactivity that may be lower in infants and possibly the elderly (17). The choice of tests should be guided by the detailed clinical history. The use of good quality food allergen extracts, characterized by demonstration of clinical efficacy and the presence of relevant allergens is strongly recommended when available. Due to a possible under-representation of minor allergens or instability of the allergenic proteins false negative reactions can occur. Whenever these types of extracts are not available and/or minor- or instable allergens are relevant for the sensitization (i.e. most fruits and vegetables), fresh foods should be used. Only trained healthcare professionals, able to interpret results and manage possible adverse reactions, should perform SPTs. These tests are performed on the forearm or upper back. Negative (saline 0.9%) and positive (histamine 10mg/ml) controls are required and the maximum wheal diameter is reported with an arbitrary positive cut-off diameter ≥ 3mm after 15 minutes (18, 19). There are numerous variables to be considered when performing and interpreting SPT including lancet type, recording of wheal diameter, timing, age, sex, and site of testing (18, 20). In addition, it should be considered that European parameters may differ from North American ones. For food allergy, intradermal skin testing is not recommended because of its low specificity, high potential for irritant reactions and risk for systemic reactions, except in particular situations, e.g. alpha-gal allergy (21).

In our systematic review (Chapter 1.3) we found reasonable sensitivity (70-100%), although less for most plant food allergies, but moderate specificity (40-70%) both for sIgE and SPT using the DBPCFC as the reference test (9). Sensitivity and specificity of serum IgE testing and SPT varied depending on the food being tested and due to the heterogeneity of studies with respect to inclusion criteria for patients, their geographic background, and their age and ethnicity, as well as recruitment processes. High quality performance of these tests is observed for allergens such as peanut, egg, milk, hazelnut, fish and shrimp, but less so for soy and wheat (9). For other plant-derived (carrot, celery, kiwi, lupine, maize and melon) or animal-derived foods (chicken and pork) only single studies were included in the recent systematic analysis.

sIgE and SPT tests are good to confirm or rule out involvement of IgE in (self-) reported food hypersensitivity. Interpretation is improved when presenting features and the magnitude of results are taken into account (Appendix I-C). However, they are often unable to differentiate between clinical relevant allergy and tolerance and oral challenges are therefore required.

Atopy patch test

Due to the lack of standardized test substances and the lack of studies showing advantages of Atopy Patch Test (APT) over SPT or sIgE, APTs are not recommended for routine diagnosis of food allergy (22, 23).

Elimination diet

An elimination diet for diagnostic purposes consists of the avoidance of the food(s) suspected of triggering allergic reactions based on the clinical history, allergy-focused diet history and adjunct allergy testing such as SPT and sIgE. The duration of the avoidance should be no longer than necessary to achieve a significant relief of symptoms, usually two to four weeks for IgE mediated symptoms and longer for non-IgE ones (e.g. up to six weeks for EoE). The diet should be thoroughly monitored and results evaluated to establish or refute the diagnosis to prevent unnecessary food restrictions. If the effect of the avoidance is limited, the diet needs to be carefully re-evaluated in case potential food allergens have been overlooked. Co-factors may also be implicated. For cow’s milk allergy, extensively hydrolysed formula may not be effective in achieving remission, and an amino acid based formula may be required. When a properly performed elimination diet
does not ameliorate the symptoms, food allergy to the eliminated foods is highly unlikely. The avoidance phase should be followed by a planned reintroduction of the eliminated food(s). Where there is no risk of a severe reaction, reintroduction may occur at home. A reported clinical reaction should be confirmed by OFC under medical supervision.

**Oral food challenges**

Oral food challenges (OFCs) are usually required to confirm the diagnosis of food allergy, to monitor food allergy or to prove oral tolerance to a given food (Table 4). There are guidelines, including one from the EAACI (24, 25) and a recent PRACTALL consensus (26), that describe procedures of OFCs in detail. These recommendations deal with the many variables involved in designing a patient specific challenge. These include patient selection, safety criteria, type and quantity of the food allergen to be administered, timings between doses, outcome criteria, observation periods and recipes to be used. Some of the key recommendations are summarized in Table 5.

Oral food challenges can be performed in an open or blinded manner. Blinded challenges can be single- or double-blinded. In many cases an open OFC with an objective unequivocal reaction is sufficient for the diagnosis of food allergy. The double-blind, placebo-controlled food challenge (DBPCFC) is considered the gold standard diagnostic test for the diagnosis of food allergy. However, a negative open challenge of a regular age appropriate serving or the negative outcome of the administration of a cumulative dose of the previous challenge on another day (27) is required for confirming the result of a negative DBPCFC (Figure 2). DBPCFC is time-consuming and resource-intensive to undertake. A negative OFC may be useful as a first step in ruling out food allergy. In patients with atopic eczema, subjective

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**Table 4** Indications for oral challenge tests

<table>
<thead>
<tr>
<th>Indication</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demonstrate allergy</strong></td>
<td>Uncertain diagnostic outcome despite use of detailed clinical history and IgE sensitisation testing.</td>
</tr>
<tr>
<td></td>
<td>Suspected food allergy reaction for which the cause is uncertain despite allergy testing (e.g. composite meal eaten).</td>
</tr>
<tr>
<td></td>
<td>Determine threshold dose of causative allergen.</td>
</tr>
<tr>
<td><strong>Demonstrate tolerance</strong></td>
<td>When allergy tests suggest tolerance but food has never been eaten and patients and/or parents too cautious to introduce at home.</td>
</tr>
<tr>
<td></td>
<td>Non clinically relevant cross-reactivity suspected, e.g. a patient with a low positive IgE result to hazelnut but high positive birch pollen sensitization.</td>
</tr>
<tr>
<td></td>
<td>When the diet is restricted due to a suspicion that one or more foods is resulting in delayed allergic symptoms (e.g. eczema).</td>
</tr>
<tr>
<td></td>
<td>Allergy suspected to have been outgrown.</td>
</tr>
<tr>
<td><strong>Monitor therapy for food allergy</strong></td>
<td>To monitor response to immunomodulatory treatment in research setting.</td>
</tr>
</tbody>
</table>
or suspected psychological symptoms the DBPCFC is superior to an OFC. The food should be blinded for taste, smell, texture and appearance (consistency, colour and shape). The placebo and the active food should be sensory indistinguishable from each other.

In order to avoid severe reactions, patients receive the food in titrated doses often with half-logarithmic (9) dose increments, at set intervals. For many foods such as cow’s milk, hen’s egg, peanut or tree nuts dose ranges from 3mg to 3g of food protein seem sufficient in clinical practice (see Appendix I-D).

Food allergy challenges are usually stopped if objective clinical reactions are observed or the last dose is consumed without clinical symptoms. Immediate reactions usually appear within two hours after the last food intake, atopic eczema may worsen several hours or days following an oral challenge. Urticaria and/or angioedema are the most common objective signs seen, gastrointestinal, respiratory or cardiovascular system involvement are also common.

To optimize safety, vital signs should be closely monitored during OFC and equipment and appropriately trained staff should be in place to deal with allergic reactions – including anaphylaxis.

For patients with non-IgE mediated reactions challenges tailored on the individual modalities of reactions should be designed.

**Recommendations Box 3-D**

**Promising novel diagnostic approaches**

In molecular or component-resolved diagnostic tests (CRD), slgE antibodies are measured against individual allergenic molecules from foods with the potential to improve the specificity of serum IgE testing and the specificity for selected food. This can be performed in either single test formats or in a microarray, testing a range of purified allergens simultaneously. For peanut allergy, determination of slgE for the major allergen, Ara h 2, showed sensitivity of 100% and specificity of 70-80% in two recent studies (28, 29). The determination of omega-5-gliadin proved to be of high
diagnostic relevance in exercise induced food allergy to wheat in a number of recent case reports and cohort studies (30) as well as the determination of rGly m 4 for allergy to soy milk in birch sensitized patients (31). For certain fruits (i.e. apple, peach, kiwi and melon), vegetables (i.e. carrot and celery), tree nuts and peanut, soy, fish and shrimp, CRD are also available and provide better insight into sensitization patterns (29). The technique of CRD is promising and broadly studied, and some important clinical results are summarized in Appendix I-E. Evidence from well-designed randomized controlled studies on the diagnostic test accuracy of CRD is still required to properly assess its diagnostic value (see Box 3B).

Basophil activation tests (BAT) have been applied in the diagnosis of cow’s milk, egg and peanut allergy (28, 32, 33) as well as in the diagnosis of pollen-food syndromes in small clinical studies (34, 35). BAT has shown higher specificity and negative predictive value than SPT and sIgE, without losing sensitivity or positive predictive value. However, BAT requires a specialized laboratory setting and large clinical studies on its diagnostic performance are lacking. Thus the use of this promising test is still limited to research purposes on food allergy.

Another promising research area is the determination of IgE antibodies against overlapping synthetic linear peptides of food allergens, as it has been performed for milk (36-38), peanut (39, 40), egg (41) and shrimp (42, 43).

**Diagnostic workup of gastrointestinal non-IgE mediated symptoms**

Infants in the first year of life may present with gastrointestinal food related clinical manifestations such food protein induced enterocolitis syndrome (FPIES), proctocolitis and enteropathy (44). Usually patients have negative food specific IgE testing (see Table 2). The diagnosis is based on symptoms, clinical history, elimination diet for up to three weeks and specifically designed OFCs (45). Endoscopy with biopsies might be helpful in confirming bowel inflammation. Currently there is scarce evidence that APT is helpful in diagnosing this form of food allergy (46).

Eosinophilic esophagitis (EoE) is defined as a chronic, immune/antigen-mediated esophageal disease, characterized clinically by symptoms related to esophageal dysfuction and histologically by eosinophil-predominant inflammation. All age groups can be affected and the current estimated prevalence is around 1 in 24,000 adults (47). Adult patients mostly present with dysphagia, less frequently with retrosternal pain and food bolus impaction, whereas the symptom presentation in children is much more variable and includes failure to thrive, vomiting, regurgitation, thoracic and abdominal pain. EoE is diagnosed by an upper endoscopy and biopsies (48). Biopsies should be performed when the patient has been treated for at least six weeks with double the standard dose proton pump inhibitors to rule out esophageal eosinophilia caused by gastro-esophageal reflux disease (GERD) and to exclude proton-pump inhibitor responsive esophageal eosinophilia. Other disorders associated with eosinophilic gastroenteritis such as Crohn's disease, celiac disease, achalasia, or eosinophilic gastroenteritis should be ruled out. Approximately 15–43% EoE patients are diagnosed with food allergies and sensitization rate to aeroallergens is up to 80%. A close collaboration between gastroenterologists and allergists is essential to optimize management of patients with EoE (47).

**Unconventional tests including specific IgG testing**

A number of expensive diagnostic alternative approaches are sometimes promoted to physicians and often used by complementary and alternative medicine practitioners in cases of suspected food allergy. Examples are bioresonance, kinesiology, iridology, hair analysis, cytotoxic test, and IgG and IgG4 determination. These tests are not currently validated and cannot be recommended in diagnosing food allergy (49-53). For example, IgG-measurements cannot be correlated with any clinical symptoms or disease. Food specific IgG4 levels indicate that the atopic individual has been repeatedly exposed to high doses of food components, which are recognized as foreign proteins by the immune system. Therefore, EAACI gave a clear recommendation not to use these tests (54).
MANAGEMENT OF FOOD ALLERGY

The clinical management of food allergy includes short-term interventions to manage acute reactions and long-term strategies to minimize the risk of further reactions. The latter aim is primarily achieved through dietary modification, education and behavioral approaches to avoid allergens and pharmacological and non-pharmacological management strategies for further reactions. There is growing interest in the effectiveness of potential immuno-modulatory treatment approaches, including sublingual and oral immunotherapy to induce tolerance (55).

Management of acute reactions

Most foods contain proteins which may be allergenic and cause food allergy and, in some cases, anaphylaxis. Recently severe reactions have been attributed to carbohydrate components (e.g. alpha gal (21)). Assessment of the risk of severe reactions is crucial in successfully managing patients with food allergy. The risks vary in different patient subgroups; for example patients with previous anaphylaxis or severe asthma have a higher risk than other patients; known cofactors include non-steroidal anti-inflammatory drugs (NSAID), exercise, infections, and mastocytosis. For detailed guidance on the emergency management of anaphylaxis, readers are referred to the EAACI anaphylaxis guidelines (Chapter 4.3) (76).

In our systematic review (Chapter 1.4) we found weak evidence to support the benefits of H1 antihistamines for children and adults with acute non-life threatening symptoms from food allergy in three randomised trials and two non-randomised comparisons (8). Importantly, there is no evidence for efficacy of antihistamines in the treatment of more severe symptoms. The prophylactic administration of antihistamines can mask early symptoms of anaphylaxis and lead to delayed treatment of dangerous reactions with adrenaline (epinephrine).

Recommendations Box 4-A

Long-term management strategies

Elimination diet and dietary interventions

Dietary avoidance is the key intervention in the management of food allergy resulting in complete or almost complete resolution of symptoms. Little research has been published about dietary eliminations due to the difficulty to perform RCTs in subjects for ethical issues. The findings from the few studies available (57-60) are mixed, and all had a high risk of potential bias. The lack of evidence does not mean that elimination diets are not effective, just that any recommendations made about elimination diets may need to rely on expert opinion and experience rather than a high quality research base.

Dietary restrictions should eliminate the culprit food allergen(s) and be tailored to the individual’s specific allergic and nutritional needs. This will cover a wide spectrum of issues such as the nutritional needs of food allergic infants who are currently being introduced to solid foods, which are very different, form the nutritional needs of adults with primary or secondary fruit and vegetable allergies. Extensive and long-term avoidance should be carefully monitored as it can result in nutritional compromises and impair quality of life. Ideally the patient should receive proper counselling by a dietician with specific competence in food allergy. This is particularly important in infants and children. In addition, it is crucial to take into account that individual tolerance levels to the allergenic food may differ and change overtime, especially in children, and may affect the stringency of avoidance advice. In breast-fed infants suffering symptoms due to maternal intake of food allergens, the mother should eliminate the foods in question and following a dietetic review, receive a calcium supplement following a dietetic review if cow’s milk, cow’s milk substitutes and derivatives are eliminated.

Education is the key pillar of an effective long-term elimination diet. Patients, their families, close relatives and caregivers should be aware of risk situations, and should be instructed in reading labels and how to avoid the relevant food allergens both in and outside the home (e.g. at restaurants). They should know that European Union (EU) directives ask for the declaration of allergenic ingredients in foods and be informed about precautionary labelled foods. They should also be provided with information on possible substitute products for most food allergens.

Patients should be re-evaluated at regular intervals to assess whether they have developed tolerance to avoid inappropriate or unnecessarily lengthy dietary elimination. This is discussed below.
# Box 4  EAACI recommendation on the management of food allergy

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A - ACUTE MANAGEMENT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The patient at risk of severe reactions should be properly and timely identified</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>There is evidence to support the benefits of antihistamines for children and adults with acute non-life threatening symptoms from food allergy.</td>
<td>III</td>
<td>C</td>
<td>(8)</td>
</tr>
<tr>
<td>The prophylactic application of antihistamines is not recommended.</td>
<td>V</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>Mast cell stabilisers are not recommended for the prophylactic treatment of food allergy.</td>
<td>III</td>
<td>C</td>
<td>(8)</td>
</tr>
<tr>
<td><strong>B - LONG-TERM MANAGEMENT STRATEGIES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B1 - ELIMINATION DIET</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A sufficient elimination diet should be based on a formal allergy diagnosis identifying the food allergen(s) responsible of the patient’s symptoms/reactions. The indications should be re-evaluated at appropriate intervals.</td>
<td>IV</td>
<td>D</td>
<td>(57, 58, 60)</td>
</tr>
<tr>
<td>Appropriate dietary avoidance is the key treatment in the management of food allergy.</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>Patients with food allergy who are on long term elimination diets should have access to appropriate dietetic counseling, ideally by a diettian with competencies in food allergy, and regular monitoring of growth (in children).</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>Extensively hydrolysed cow’s milk formulas with documented hypoallergenicity can be recommended as first choice for the treatment of cow’s milk allergy, especially in infants and young children. Amino acid formulas can also be recommended especially for the subgroup of patients with more severe symptoms.</td>
<td>I</td>
<td>A</td>
<td>(61, 63, 65, 89)</td>
</tr>
<tr>
<td>Soy formulas should not be recommended before 6 months of age and at any age in the presence of gastrointestinal symptoms. From 6-12 months it can be considered on a case-by-case basis.</td>
<td>I</td>
<td>B</td>
<td>(8)</td>
</tr>
<tr>
<td>Currently, probiotic supplements cannot be recommended for the management of food allergy.</td>
<td>I</td>
<td>D</td>
<td>(8, 75)</td>
</tr>
<tr>
<td><strong>B2 - EDUCATION AND RISK ASSESSMENT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients and caregivers need to be informed about the foods that should be avoided and practical advice given on avoidance measures, how to recognize a further reaction and the self-management of these reactions.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>The diagnosis of food allergy should, with permission, be communicated to all relevant caregivers.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Patients/carers should be encouraged to join an appropriate patient support organization.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>All patients with food allergy require a management plan with appropriate education for the patient, caregiver including school.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Education should cover allergen avoidance, symptom recognition and indication for specific treatment and administration of specific medication.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Absolute indications with adrenaline auto-injector include previous anaphylaxis to any food, food allergy associated with persistent or severe asthma and exercise-induced, food-dependent anaphylaxis</td>
<td>IV</td>
<td>D</td>
<td>Expert opinion, refer to the anaphylaxis guidelines chapter</td>
</tr>
<tr>
<td>Recommendations</td>
<td>Evidence level</td>
<td>Grade</td>
<td>Key reference</td>
</tr>
<tr>
<td>-----------------</td>
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</tr>
<tr>
<td>Relative indications for adrenaline auto-injector with food allergy include (1) food allergies that are likely to be persistent; (2) mild-to-moderate allergic reaction to peanut and/or tree nut (3) mild-to-moderate reaction to very small amounts of food and (4) specific high risk groups, e.g. adolescents, young adult males, poor access to medical care.</td>
<td>IV-V*</td>
<td>C-D*</td>
<td>Expert opinion, refer to the anaphylaxis guidelines chapter</td>
</tr>
<tr>
<td>Adrenaline should be immediately administered for cardiovascular symptoms and/or respiratory symptoms such as altered voice, stridor or bronchospasm that are thought to be induced by food allergy.</td>
<td>IV</td>
<td>C</td>
<td>Refer to the anaphylaxis guidelines chapter</td>
</tr>
<tr>
<td>Short acting beta agonists should be included in the management plan for all patients with co-existing asthma and should be administered for bronchospasm after adrenaline has been administered.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion, refer to the anaphylaxis guidelines chapter</td>
</tr>
<tr>
<td>Patient held glucocorticosteroids may be given with reactions to possibly prevent late phase respiratory symptoms (self administered if travelling far from medical care, otherwise in emergency center).</td>
<td>V</td>
<td>D</td>
<td>Expert opinion, refer to the anaphylaxis guidelines chapter</td>
</tr>
<tr>
<td>Any patient who has received adrenaline should be reviewed in an emergency department.</td>
<td>IV</td>
<td>D</td>
<td>Expert opinion, refer to the anaphylaxis guidelines chapter</td>
</tr>
</tbody>
</table>

### B3 - SPECIFIC IMMUNOTHERAPY

Food allergen-specific immunotherapy for primary food allergy is a promising immune-modulatory treatment approach (I), but it is associated with risk of adverse reactions, including anaphylaxis (I); it is therefore not currently recommended for routine clinical use.

For patients with respiratory or other allergy symptoms to inhalant allergens that may also cause cross reactive food allergy, specific immunotherapy is only recommended for the treatment of the respiratory symptoms, not for cross-reactive food allergy.

### B4 - ANTI-IGE

The use of anti-IgE alone or in combination with specific immunotherapy is currently not recommended for the treatment of food allergy although it represents a promising treatment modality.

### B5 - CHALLENGES AT REGULAR INTERVALS TO ASSESS ACHIEVEMENTS OF TOLERANCE

OFC should be performed at regularly at intervals, as appropriate for the specific food and patient’s history, in order to assess achievement of tolerance.

Specific IgE testing (in vitro and skin prick test) has limited value in guiding adequately the timing of oral food challenges for development of tolerance.

### B6 - COFACTORS

In food allergy reactions, the potential augmenting role of cofactors (e.g. exercise, NSAID, omeprazole, alcohol intake) should be assessed in a structured history.

In allergic reactions occurring after exercise, NSAID or alcohol intake, an underlying allergy to foods consumed in the previous hours should be assessed (especially gliadin sensitization or LTP in southern Europe).

* Range of levels of evidence and grades are due to range of indications.
** Range of levels of evidence and grades are due to range of different cofactors.
Cow’s milk substitutes

In children with cow’s milk allergy, several substitutes are available. In infants and young children these products are especially necessary to ensure a diet that is adequate for growth and development. In infants younger than six months, such formulas have to fulfill the general requirements for full nutrition until the introduction of complementary foods. In addition, these substitutes may also be required in older children to ensure a satisfactory calorie intake. There is some moderate level evidence about some alternatives to cow’s milk. However, most of the research is of low quality and there are a relatively small number of studies about each type of alternative formula. There is some evidence to suggest that extensively hydrolyzed formula, amino acid-based formula and soy-based formula, may all be useful long-term management strategies. Extensively hydrolysed cow’s milk formulas are the first choice as an alternative to cow’s milk. However, amino acid-based formulas are the only completely non-allergenic formula and they can be effective in patients not responding to extensively hydrolysed formulas and in subgroups of children. These include infants with severe growth faltering (61-63) those with, cow’s milk protein allergy with severe symptoms and non-IgE mediated syndromes such as food protein induced enterocolitis and enteropathies, eosinophilic gastroenteropathies. Soy formulas may be useful provided that nutritional evaluation regarding the phytate and phyto-oestrogens content is considered, they cannot be recommended before 6 months of age. Rice hydrolyzed formulas have been recently introduced to the market in some European countries and further research is needed to compare these formulas with extensively hydrolyzed formula and soy formulas. The substitutes for cow’s milk should fulfill the criteria for documented hypoallergenicity and for nutritional adequacy (64, 65). To achieve these requirements, the formula should be investigated in consecutive patients with both IgE and non-IgE mediated cow’s milk protein allergy (66). Some extensively hydrolyzed formulas have been investigated and fulfill these criteria (62, 67-69). In addition, attention should be paid to taste and price as reimbursement policies for these types of formulas differ across the EU.

Based on several reports partially hydrolysed cow’s milk based formulas are not regarded as safe for patients with cow’s milk allergy (70, 71). There is less evidence regarding other mammalian milk. Goat and sheep’s milk are very similar to the proteins in cow’s milk, and therefore should not be recommended for patients with cow’s milk allergy (72). Camel, donkey or mare’s milk have been shown to be less cross-reactive than goat’s milk, although evidence for recommendations is lacking as well as for chicken-based formula (73) or meat-based formula (74). In summary, it is recommended that the choice of an appropriate cow’s milk substitute should be assessed carefully balancing the following factors; age, type of food allergy (IgE / non IgE) coexistence of gastrointestinal symptoms, history of life threatening reactions and nutritional requirements as well as cost effectiveness.

Probiotics and prebiotics

Probiotics have been investigated as another option for management of patients with food allergy, particularly cow’s milk allergy, either added to formulas or given as a supplement. Evidence that probiotic supplements have preventative or therapeutic activity for food allergy is lacking (8) and further research is needed to make recommendations in this area (75).

Recommendations Box 4-B1

Pharmacological treatment

Studies on the prophylaxis of food allergy with mast cell stabilizers have led to different clinical results (Chapter 1.4) (8). Four randomized trials and two non-randomized comparisons found that mast cell stabilizers reduced symptoms of food allergy but three randomized trials found no benefits. Overall, the evidence is not sufficient to recommend mast cell stabilizers for the prophylactic treatment of food allergy.

Education and risk assessment

Education and training are a fundamental part of managing food allergies and should be combined with a risk assessment of those patients at risk of severe reactions (76). A personalised management plan, including an emergency plan, should be issued as part of the overall educational package offered to patients (family and caregivers; see also anaphylaxis guidelines). The plan should be personalised to take into account the many variables that may influence the identification and treatment of allergic reactions: age of the patient, literacy of patient and family, type and range of food allergy, concomitant disease, geographic location and access to medical support. Training should cover patient-specific avoidance strategies at home and in the wider environment, interpretation
of warning signals, when and how to treat reactions including use of self-injectiveable adrenaline if appropriate (3). All professionals, including family doctors, school nurses, dieticians, school teachers and nursery staff, should be trained. There is some evidence that a multidisciplinary clinical approach (8) and the provision of educational printed and online materials for food allergy (10) improve knowledge, correct use of adrenaline auto-injectors and reduce reactions (see anaphylaxis guidelines).

Recommendations Box 4-B2

Co-factors
Several augmentation factors are known to increase the severity of some food allergic reactions. Sometimes these factors are even obligatory to elicit symptoms of food allergy. Among the best characterised factors are physical exercise and NSAID, others include alcohol, fever and acute infection. One example is wheat-dependent, exercise-induced anaphylaxis due to omega-5-gliadin sensitization (30); other allergens such as lipid transfer proteins (LTP) seem to be relevant in certain geographic areas (77, 78). Potential co-factors should be assessed in any case of food allergy.

Recommendations Box 4-B6

Immunomodulation

Specific immunotherapy of food allergy
For the treatment of food allergy, specific immunotherapy with food allergens using the subcutaneous, oral or sublingual route have been assessed (8) (chapter 1.4). Most controlled studies have been performed with peanuts, hazelnut, hen’s egg or cow’s milk. For pollen-associated food allergy, immunotherapy has been performed with, subcutaneous or sublingual pollen allergens and the oral or sublingual food allergen.

Two low quality controlled crossover studies suggest that subcutaneous immunotherapy with food allergens is effective. For pollen-associated food allergy, three very low quality RCTs (79, 80) and two non-randomized studies showed conflicting efficacy for the injection treatment with pollen allergen.

Four randomized trials found that sublingual immunotherapy (SLIT) with food allergens was associated with improved tolerance and reduced symptoms for those with peanut, hazelnut and peach allergies (81, 82). One trial with birch pollen allergen found no benefit in subjects with apple allergy (83).

For oral immunotherapy two systematic reviews, eight randomized trials and three non-randomized comparisons found that oral immunotherapy with food allergens was associated with improved tolerance and reduced symptoms for children and adults with various food allergies (8). However, around 90% of participants have side effects although these were usually not severe. Oral immunotherapy was more efficacious for desensitization to cow’s milk than SLIT but was accompanied by more systemic side effects in one study (84). One randomized trial found no benefit (85). The two systematic reviews found mixed evidence and suggested that oral immunotherapy should not currently be recommended as routine treatment (86, 87). In light of its potential benefit, it should be performed only in highly specialized centres, with expert staff and adequate equipment, and in accordance with clinical protocols approved by local ethics committees.

The evidence from these studies supports the need for further exploration of immunotherapy with food allergens (8), although especially in subcutaneous and oral immunotherapy the treatment seems to be associated with significant adverse effects. In regard to pollen-associated food allergy there is conflicting evidence on efficacy of subcutaneous and sublingual immunotherapy with pollen allergens; these therapeutic interventions should only be used for the pollen allergy symptoms.

Recommendations Box 4-B3

Anti-IgE treatment
Omalizumab is a humanized monoclonal anti-IgE antibody, which is licensed for the treatment of allergic asthma. The impact of omalizumab and another anti-IgE antibody (TNX-901) on food allergy have been investigated (8) (chapter 1.4). Increased thresholds of tolerance to food allergens were found in a subgroup of participants. Studies suggest that the clinical benefits of omalizumab are achieved after just a few doses of omalizumab. Moreover, it has been demonstrated that more rapid up-dosing and higher doses of milk protein could be administered when omalizumab was used as an adjunct therapy (88).
Challenges at regular intervals to assess development of tolerance

As tolerance can be acquired spontaneously for some food allergens, particularly in children, or can develop with pollen sensitization. There is therefore a need to regularly re-evaluate patients to prevent inappropriate or unnecessarily lengthy dietary eliminations that may impair the quality of life, affect normal growth, and incur unnecessary healthcare costs. Repeated IgE testing can be helpful to determine if sensitization is decreasing (common in egg and milk allergy) and help to identify associated allergies (e.g., peanut, associated with tree nut, sesame (20)).

Currently, OFC are the only tests that can predict with adequate certainty the achievement of tolerance although it has been shown that low food allergen specific IgE levels at diagnosis and a decrease over time both correlate with clinical tolerance. It is therefore recommended that OFC should be performed at regular intervals in order to avoid unnecessary dietary restrictions. The eliciting food may influence this process as, for example, in cow’s milk and hen’s egg allergy the majority of children will become tolerant within a few years while most patients with peanut or tree nut allergy remain allergic throughout their life. In cow’s milk or hen’s egg allergy intervals for re-evaluation might be every 6-12 months while for peanut and tree nut allergy OFC every two years in the absence of an accidental reaction would be more appropriate.

Management of eosinophilic esophagitis

Symptomatic EoE patients should be treated not only for quality of life reasons but also to reduce the risk for the occurrence of the potentially dangerous food bolus impactions. Untreated eosinophil-predominant inflammation leads to esophageal remodeling with narrowing of the esophageal caliper and a loss of function. Treatment modalities include drugs, diets, and esophageal dilation. Swallowed topical corticosteroids (budesonide or fluticasone) and diets have shown to reduce symptoms and eosinophilic infiltration. The following diet types are available: amino-acid based formula diet (often necessitates a feeding tube), targeted elimination diet (according to allergy workup) and empiric elimination diet. Esophageal dilation of strictures can increase esophageal diameter and improve symptoms, however, it does not influence the underlying inflammation. The long-term treatment strategies are not yet defined. Close collaboration between allergists/immunologists and gastroenterologists is advised (47).

Recommendations, gaps and research needs in the management of food allergy are summarized in Box 4 and 6 respectively.

Conclusions and future perspectives

Food allergy appears to be an increasing burden, which needs to be properly addressed in a structured diagnostic and management approach. The overall body of evidence indicates that patients’ clinical history, through the use of structured questions on symptoms, food and background information, should guide the allergy testing as IgE sensitization does not always equate with clinically relevant food allergy. SPT and sIgE (and probably CRD) offer high sensitivity in relation to a range of allergens implicated in IgE mediated food allergy. Direct comparisons among the tests are difficult given the limited body of evidence in which these tests have been compared in the same population. There is greater variation in the specificity of these tests, since they indicate sensitization that may not be of clinical relevance, with specific IgE tending to have a higher rate of false positive results. There is limited evidence for the value of APT in diagnosis. The comparability of the local population and the relative availability, safety and costs of the tests will influence local protocols for diagnostic evaluation.

An elimination diet based on an allergy focused clinical history and allergy testing should be followed until a significant relief of symptoms is achieved. Careful consideration should be given to the nutritional completeness of patients’ diet. Given the limitation of other tests, OFC (ideally DBPCFC) are still the gold standard in IgE and non-IgE mediated food allergy in order to establish a firm diagnosis, determine threshold reactivity, assess tolerance and the response to immunomodulation. Facilities for OFC are lacking and reimbursement policies vary across national European countries. Efforts should be provided to adequate diagnostic facilities and capabilities to all food allergic patients in Europe.
### Box 5 Gaps and research needs in the diagnosis of food allergy

<table>
<thead>
<tr>
<th>Gaps in the evidence</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A - PATIENT’S CLINICAL HISTORY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of studies comparing the accuracy of predictions made using standardised...</td>
<td>Clinical studies.</td>
<td>1</td>
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<tr>
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<tr>
<td>More studies modelling the use of history and tests to predict the diagnosis of...</td>
<td>Development of mathematical models.</td>
<td>1</td>
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<tr>
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<tr>
<td><strong>B - DETERMINATION OF SENSITIZATION</strong></td>
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</tr>
<tr>
<td>Lack of well-designed studies to assess diagnostic utility of different tests...</td>
<td>There is an urgent need for well-designed clinical studies on both...</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>including CRD and novel approaches including BAT and linear IgE epitope...</td>
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<tr>
<td><strong>C - ELIMINATION DIETS FOR DIAGNOSTIC PURPOSES</strong></td>
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<tr>
<td>Best approach to elimination diets.</td>
<td>Need for studies on the procedure of avoidance diets during the diagnostic...</td>
<td>2</td>
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<tr>
<td></td>
<td>phase.</td>
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<td></td>
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<tr>
<td><strong>D - ORAL CHALLENGE TESTS</strong></td>
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<tr>
<td>Lack of standardized protocols for open and blinded challenges in...</td>
<td>Need for more studies to harmonize protocols for open and blinded...</td>
<td>2</td>
</tr>
<tr>
<td>adults and children.</td>
<td>challenges in relation to age.</td>
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<tr>
<td>Comparison between open versus blinded challenges.</td>
<td>More studies needed to investigate the bias between open versus blinded...</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>challenges.</td>
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<tr>
<td>Comparison of different challenge protocols – open versus blinded in different...</td>
<td>More clinical studies.</td>
<td>2</td>
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<tr>
<td>different age groups and in children with different allergic disease.</td>
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<tr>
<td>Lack of evidence addressing the utility of different challenge protocols in...</td>
<td>More research needed in secondary and tertiary criteria level centres.</td>
<td>3</td>
</tr>
<tr>
<td>different clinical setting.</td>
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<tr>
<td>Scarce evidence in validation of diagnostic criteria: subjective versus...</td>
<td>More research needed in interpretation of symptoms...</td>
<td>2</td>
</tr>
<tr>
<td>objective criteria during the challenges.</td>
<td>between and within individuals.</td>
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<tr>
<td>Lack of validated age-appropriate OFC recipes (active and placebo).</td>
<td>More studies on validation of recipes.</td>
<td>2</td>
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<tr>
<td><strong>E - UNCONVENTIONAL TESTS INCLUDING SPECIFIC IgG TESTING</strong></td>
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<tr>
<td>Lack of knowledge among the public of the ineffectiveness of these tests.</td>
<td>Need of properly designed information and education programmes on allergy...</td>
<td>2</td>
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<td>diagnostic tests for health professionals and the public. Need to...</td>
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<td>facilitate access to qualified allergy services.</td>
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<tr>
<td>Lack of understanding of the costs related to misdiagnosis.</td>
<td>Socio-economic evaluation of misdiagnosis of food allergy.</td>
<td>2</td>
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</tbody>
</table>
### Box 6  Gaps and research needs in the management of food allergy

<table>
<thead>
<tr>
<th>Gaps in the evidence</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A - ACUTE MANAGEMENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomarkers for identifying patients at risk of severe reactions.</td>
<td>More research in biomarkers identification.</td>
<td>1</td>
</tr>
<tr>
<td>Lack of effective prophylactic drugs in the management of food allergy.</td>
<td>More research for the development of prophylactic drugs.</td>
<td>2</td>
</tr>
<tr>
<td><strong>B - LONG-TERM MANAGEMENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B1 - ELIMINATION DIET</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The long term effect of dietary avoidance on nutrition and quality of life.</td>
<td>High quality prospective studies of infants and young children focused on efficacy, growth and quality of life. High quality prospective studies of adults focused on efficacy, nutritional status and quality of life.</td>
<td>2</td>
</tr>
<tr>
<td>The possible effect of using modified food allergens (e.g. baked milk and egg) to improve and accelerate tolerance.</td>
<td>High quality prospective randomised controlled trials of infants and young children and adults with documented food allergy.</td>
<td>1</td>
</tr>
<tr>
<td>Indications for the use of amino acid formulas versus extensively hydrolysed formulas.</td>
<td>Large cohort studies of children with cow’s milk allergy comparing the cost effectiveness of these two types of formulas at different ages and with different clinical symptoms.</td>
<td>2</td>
</tr>
<tr>
<td>Long term nutritional value of rice and soy formulas.</td>
<td>High quality prospective randomised controlled trials of infants and young children with documented food allergy.</td>
<td>2</td>
</tr>
<tr>
<td>The effect of supplementation with different probiotic strains for management of food allergy.</td>
<td>High quality prospective randomised controlled trials of infants, young children and adults with documented food allergy.</td>
<td>2</td>
</tr>
<tr>
<td><strong>B2 - EDUCATION AND RISK ASSESSMENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A multidisciplinary approach (e.g. physician, clinical nurse specialist, dietician with simulation training) should be taken to allow patients to achieve competence in managing their food allergy.</td>
<td>Randomized controlled studies looking at the how different facets of education impact on patients’ competency.</td>
<td>2</td>
</tr>
<tr>
<td>The optimal approach to educating patients and their caregivers.</td>
<td>Randomised controlled studies comparing the impact of different educational approaches to patients’ competency.</td>
<td>2</td>
</tr>
<tr>
<td><strong>B3 - SPECIFIC IMMUNOTHERAPY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What are the effectiveness, risks, cost-effectiveness and long-term benefits and risks of food allergen specific immunotherapy for primary food?</td>
<td>Large multicentre trials for different allergens and route of specific immunotherapy with foods.</td>
<td>1</td>
</tr>
<tr>
<td>Long term outcomes needs to be determined.</td>
<td>Clinical trials applying longer observation periods.</td>
<td>1</td>
</tr>
<tr>
<td>What are the effectiveness, risks and cost-effectiveness of allergen specific immunotherapy to pollens in those with pollen associated food allergy?</td>
<td>Prospective clinical studies.</td>
<td>2</td>
</tr>
</tbody>
</table>
The optimal management of food allergy consists of a multi-disciplinary and multi-faceted approach, which encompasses treatment of acute episodes of the disease, identification of patients at risk of severe reactions and long-term management strategies in order to minimize recurrences of reactions and improve quality of life.

Although there are several management strategies available, evidence of effectiveness is very limited in this context. The data on pharmacologic treatment is limited with only H1-antihistamines considered to alleviating acute symptoms but only non-life threatening ones. Dietary avoidance of properly identified culprit food(s) is the cornerstone of management. There is some evidence to recommend extensively hydrolyzed formulas with documented hypoallergenicity or amino acids formulas as alternatives to cow’s milk formula. However, few extensively hydrolyzed formulas have been investigated for hypoallergenicity in properly designed studies, particularly in children with newly documented cow’s milk protein allergy. There is currently no evidence for recommending probiotics and prebiotics with the aim to induce tolerance, although there might be new findings in this field in the near future. Patients at risk of anaphylaxis should have access to self-injectable adrenaline for treating future severe reactions. Facilitated access to allergy consultations, counseling by dietitians with competencies in food allergy, psychological interventions as well as coordination among the several healthcare professionals dealing with the various clinical manifestations of the disease should all be ideally put in place for the effective treatment of these patients.

More proactive treatment for food allergy is urgently needed to address the associated health risk and
social burden. Findings suggest that immunotherapy for food allergy through several routes (subcutaneous, sublingual, oral, epicutaneous) may help to increase tolerance with accidental exposure although the expected improvement may be small. Oral immunotherapy may be useful for IgE mediated food allergy but is associated with a significant risk of local and systemic reactions. Overall, specific immunotherapy is not yet suitable for use in routine clinical care and should be performed in specialized clinical settings under supervision by an allergist with expertise in the field. As a long term strategy, further research is required into whether immunotherapy could be offered in daily clinical practice.

Education is a key feature in the management of food allergy and should be heavily promoted to patients, families and caregivers as well as to health professionals. Developing and validating educational tools will further the establishment of vertical and horizontal networks between Centres of Excellence, allergy specialists and primary care practitioners. Implementation at the community level should be in partnership with the patient organizations (see community guidelines chapter, chapter 5.1). Adequate reimbursement from national health systems and insurance bodies for diagnostic procedures and the management strategies, including education, should be available.

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Authors’ contribution
Antonella Muraro, Chair of the EAACI Food Allergy and Anaphylaxis Guidelines Initiative, has steered and coordinated the publication. Thomas Werfel, Karin Hoffman-Sommergruber and Graham Roberts facilitated and edited these guidelines. Susanne Halken, Berber Vlieg Boestra, Kirsten Beyer, Carsten Bindslev-Jensen, George du Toit and Margitta Worm contributed to the subsection discussion. Karla Soares-Weiser, Debra de Silva, Bridget Nwaru and Sukhmeet Panesar undertook the supporting systematic reviews under the supervision of Aziz Sheikh. All authors participated in the discussion of the systematic review, the evidence table, recommendations, gaps and specific sections and approved the final version.

Conflicts of interest
Antonella Muraro has provided scientific advice for Meda. Graham Roberts has provided scientific advice for Danone and ALK-Abelló; Thomas Werfel has provided scientific advice for Meda and Novartis. Caroline Nilsson, Susanne Halken have provided scientific advice for ALK-Abelló. Barbara Ballmer-Weber has provided scientific advice for Thermo Fisher Scientific. Thermo Fisher and ALK-Abelló have provided consumables for his research activities. Tony DuBois has provided scientific advice for ALK-Abelló and received funding from ALK-Abelló to support his research activities. Margitta Worm has provided scientific advice for ALK-Abelló, Meda, Novartis and Stallergenes.Montserrat Fernández Rivas has provided scientific advice to GSK and has received funding from the European Union, the Spanish Ministry of Science and ALK-Abelló. Carsten Bindslev-Jensen has received funding from Thermo Fisher, HAL, Stallergens and Anergis, ALK, Novartis, MSD, Schering-Plough for his research activities. Victoria Cardona has provided scientific advice for ALK-Abelló. Philippe Eigenmann has provided scientific advice for Danone, Novartis, ALK-Abelló, DBV technologies and Stallergenes; he has received funding for research activities from LETI, Nestlé and Thermo Fisher. Carina Venter has produced educational material for Danone, Mead Johnson and Nestlé and has received research funding from Thermo Fisher, Danone and Mead Johnson. Berber Vlieg-Boerstra has received research funding from Danone/ Nutricia, Yakult and Mead Johnson. Debra de Silva, Sukhmeet Panesar and Aziz Sheikh have received funding for coordinating guidelines production, and generating the systematic reviews from EAACI. Aziz Sheikh has provided scientific advice to ALK-Abelló, Meda, Lincoln Medical, Thermo Fisher, Pfizer and Stallergenes; he is on the Anaphylaxis Campaign UK’s Scientific Committee, World Allergy Organization’s Anaphylaxis Special Committee, UK Resuscitation Council’s Anaphylaxis Committee and the BSACI’s Standard of Care Committee. Lars Poulsen has provided scientific advice to Nvozymes and has received funding for research from ALK-Abelló, Anergis, Biomay,
Stallergenes. Kirsten Beyer has received funding for research activities from the European Union, German Research Foundation, Berliner Sparkasse, BEA-Stiftung, Food Allergy & Anaphylaxis Network, Food Allergy Initiative, Danone, Thermo Fisher, DST Diagnostische Systeme & Technologien GmbH, Allergopharma. Gideon Lack, George du Toit and Bodo Niggemann have no conflict of interests. Karin Hoffmann-Sommergruber has received honoraria from Thermo Fisher and Milupa.

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APPENDICES:

I. Tools to support implementation:
   a. Key questions for patient’s clinical history
   b. Key observations
   c. Interpreting allergy tests
   d. Oral challenges: recommended doses
   e. Component resolved IgE studies

II. Barriers and facilitators to implementation, audit criteria and resource implications of recommendations
Appendix I: Tools to support Implementation

A: Key Questions in the patients’ history of possible food allergy

Table I-A Questions

<table>
<thead>
<tr>
<th>Description of food-induced allergic symptoms</th>
<th>What were the exact symptoms and their timing? How were the symptoms treated? What was the timing of the resolution of symptoms?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliciting food allergen</td>
<td>Which food induced the reaction? Is the allergen typical for age and country?</td>
</tr>
<tr>
<td>Timing of the reaction post exposure</td>
<td>How long after exposure did the reaction develop?</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>Is the reaction reproducible?</td>
</tr>
<tr>
<td>Food processing</td>
<td>Does the reaction happen with processed and/or raw food?</td>
</tr>
<tr>
<td>Route of allergen exposure</td>
<td>What was the route of exposure to the food?</td>
</tr>
<tr>
<td>Amount of allergen</td>
<td>How much of the food allergen did the patient have before reacting?</td>
</tr>
<tr>
<td>Concomitant diseases</td>
<td>Does the patient have other medical conditions, including atopic diseases?</td>
</tr>
<tr>
<td>Co-factors</td>
<td>Did the patient exercise or take any alcohol or drugs before or after eating the index food?</td>
</tr>
</tbody>
</table>
| Co- and cross-reactivity                    | Are related allergens eaten and tolerated? 
  | Is there cross-reactivity between inhalant allergens and food allergens? 
  | Is the patient allergic to latex? |
| Other foods                                 | Is the patient able to eat ... (name specific foods)? |
| Dietary intake                              | Is the presence of a food allergy compromising dietary intake? |
| History of previous elimination diets       | Did the patient follow elimination diets previously? Was it helpful? |

B: Key Observations

Table I-B Key observations

- Milk and egg allergy are common in early childhood but comparatively rare in adulthood. Shellfish and plant food allergies are more common in adulthood.
- An understanding of common regional allergens will guide subsequent allergy testing.

- Symptoms indicate possible underlying immunological mechanisms, namely IgE or non-IgE-mediated.
- If the symptoms are not typical of an immune-mediated reaction then a differential diagnosis must be considered.
- Confusing diagnostic scenarios in immediate-type reactions include: perioral erythema and irritation provoked by contact with skin irritants (e.g. raw tomato, citrus and berries), scromboid fish reactions, and chronic urticaria (for which food allergy is a rare cause).
- In some children, food allergy may masquerade as a food aversion or refusal, but this may also be behavioural, due to oral tactile aversions, or odour sensitivity.
- A history of severe allergic reactions determines a different risk assessment and a more stringent management plan.
• IgE-mediated allergic reactions usually occur within 30 minutes of the ingestion and mostly within 2 hours.
• Non-IgE mediated immune reactions are typically more delayed in onset.
• Non-immune mediated reactions can be of both immediate and delayed onset.

• Allergic reactions to a specific food should be consistent and develop every time the patient is exposed to that food.
• In children, peanut reactions typically present after the first known exposure, whereas other foods such as wheat, milk and fish, may present after multiple exposures.
• However adults may have eaten peanuts and tree nuts for many years before developing an allergy.

• Clinical reactivity may be influenced by processing of the food, e.g. egg allergic children commonly tolerate baked-egg protein whilst reacting to loosely cooked egg. In adults, soy may be tolerated in some forms but soy milk may provoke reactions in those with pollen-food syndrome.
• Patients with pollen-food syndrome usually tolerate cross reacting foods when eaten cooked but develop symptoms when eaten raw.

• In breast-fed infants, food allergens may be transmitted via human milk in small amounts (ng/ml)".
• Allergic reactions may occur after exposure to airborne allergen, typically fish and milk.
• A proportion of patients will react after skin contact or inhalation.

• Different patients react to different doses of the food allergen.
• The dose of allergen eaten is also important to establish tolerance, e.g. if a child has had a food regularly in very small amounts may not mean she/he would tolerate the food if she/he ate a larger amount.

• The majority of children with food allergy will have eczema, and at least 25% will go on to develop additional food allergies.
• Food allergic infants are at risk for the development of asthma; and asthma is a risk factor for more severe-food induced allergic reactions in all age groups.
• Adults with food allergy will often be sensitised or allergic to pollen, and therefore more likely to develop pollen-food syndrome. More than 50% of those with birch pollen allergy will report symptoms to plant foods due to cross-reactions.

• Asthma, medication use (esp. ACEI, β-blockers, acetyl salicylate), alcohol intake and/or exercise are factors, which may increase the severity of allergic reactions.

• Allergy to just one food is increasingly uncommon. The patient with peanut allergy is commonly sensitized to one or more tree nuts and or sesame.
• People with pollen-food syndrome often report reactions to many different fruits, nuts and vegetables.
• Some latex allergens are homologous to certain food allergens such as kiwi, avocado and chestnuts.

• Ask specifically about common allergenic foods, including foods causing co- and cross-reactivity with the index food.
• Ask whether foods which might contain the suspected allergen are tolerated, e.g. is multi-grain bread tolerated if soy is suspected.
• Ask if a child is able to consume age-appropriate quantities of specific foods, e.g. a 5 year old should be able to consume a whole egg/full glass of milk before being labelled as truly tolerant to the food.

• In the absence of dietetic supervision, all children with food allergy are at a greatly increased risk for nutritional compromise.
• Adults, who are avoiding major food groups such as milk or wheat, will also have a compromised nutritional intake.

• Elimination diets without decrease of symptoms should be stopped.
C: Interpreting allergy tests

The performance of allergy tests for the diagnosis of food allergy should ideally be validated against the gold standard investigation (i.e. the DBPCFC). There are studies, in different clinical scenarios and geographic settings that assess the diagnostic ability of allergy tests (SPT and/or sIgE) as compared to the DBPCFC. These analyses allow for the generation of 2x2 tables and sensitivity and specificity values.

Sensitivity refers to the proportion of patients with a condition who test positive. For the diagnosis of food allergy, sensitivity of SPT and sIgE is variable and allergen specific, for example for peanut it is modestly high at around >80%. Specificity refers to the proportion of persons without the condition who test negative; for food allergy the specificity of the SPT and peanut-IgE is lower than the sensitivity, for example 30% to 50% for peanut. A highly sensitive test is good at ruling out a diagnosis when the test is negative. A specific test is good at confirming a diagnosis when the test is positive.

The size of the test value (SPT and or sIgE) that is to be considered ‘positive’ dramatically alters the sensitivity/specificity of an investigation. Whilst it is useful to consider extreme values (both positive and negative) – as these carry better sensitivity or specificity – most patients seen in routine referral clinical settings will not present with test results at the extremes. Therefore, many patients have equivocal diagnostic outcome (history depending) that can only be resolved through performing an OFC.

As it is difficult to use sensitivity and specificity at the level of the individual, use is frequently made of positive and negative predictive values. The positive predictive value (PPV) is the probability that a patient has food allergy if the test is positive; the negative predictive value (NPV) is probability that the patient does not have food allergy if the test is negative. However, these predictive values are dependent on the population prevalence, the food allergen in question, background history, age, sex, geographic location, ethnicity, and concomitant allergies (e.g. eczema). It is therefore not easily possible to apply predictive values across different population and in different settings.

Given the above challenges, use is increasingly being made of likelihood ratios (LR) which offer a different diagnostic approach that is more practicable at the level of the individual patient. The use of LR’s reflects the natural thought process that is undertaken by clinicians in routine medical diagnostic practice. So a determination is made of the pre-test probability of food allergy being present prior to the test (SPT and or sIgE); with the allergy test result known, a post-test probability can then be determined by combining these two values and a decision regarding management can then be made. For the diagnosis of food allergy this is crucial to decide whether or not the patient should undergo an OFC.

The pre-test probability is determined through combining the likely risk determined through clinical history, data on the local prevalence of the disease, personal clinical experience and published reports. The use of the LR places an emphasis on obtaining a robust clinical history as well as an understanding of the disease in a local setting.

A LR reflects how many times more likely a given test result is seen in a patient who is allergic to that food compared with a patient who is tolerant. The further the LR is above 1 the stronger the evidence for the presence of the disease. A LR ≥10 is highly suggestive of food allergy.

The LR of the test – given only two allergy outcomes – can be calculated directly from sensitivity and specificity (LR = sensitivity/(1−specificity)). The post-test probability is determined by this mathematical calculation or by using a simple statistically derived nomogram (Figure 1-C1), which can simplify this calculation to percentages rather than odds.

The use of a LR has the advantage of giving us the ability to interpret allergy tests within the subject’s clinical context, as different patients in diverse clinical settings, but with the same test result, have different likelihoods of having food allergy.
**EAACI food allergy guidelines**

**Figure I-C 1** Using likelihood ratios (LR) to diagnose allergy

Figure adapted from: Fagan TJ. (90)

The three arrows are examples of clinical situations described in the Table I-C below (Red arrow refers to scenario A, green to B and blue to C).

**Figure I-C 2** Using likelihood ratios (LR) to diagnose allergy

Children and adolescents in the possible allergy box require an OFC for a definitive diagnosis. Specific IgE and SPT values are specific for peanuts. Values associated with a high likelihood of clinical allergy are lower for egg, milk, and fish. Modified from Stiefel and Roberts (91).

---

**Table I-C1** Clinical examples that relate to the diagnosis of peanut allergy

<table>
<thead>
<tr>
<th>Scenario</th>
<th>History</th>
<th>Pre-test probability</th>
<th>Test results</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5 year old, British, male. 3 previous allergic reactions soon after peanut butter ingestion</td>
<td>At least 98% chance as guided by history</td>
<td>SPT 8mm, LR approx. 17.3 (in UK)</td>
<td>Strictly avoid peanut. Institute comprehensive education and emergency plan</td>
</tr>
<tr>
<td>B</td>
<td>8 year old, French female. No allergy concerns. Sibling peanut allergic. No known peanut exposure.</td>
<td>Epidemiological risk 7%</td>
<td>No SPT obtained. Peanut sIgE 2KU/L, LR approx. 2.6</td>
<td>Post test probability 20%, consider OFC or component testing if available</td>
</tr>
<tr>
<td>C</td>
<td>4 year old, British child, with egg allergy and early-onset moderate eczema. Never eaten peanut</td>
<td>Epidemiologic risk 30%</td>
<td>SPT 3mm, LR 40.3 in UK</td>
<td>Likely allergy as post test probability 95%</td>
</tr>
</tbody>
</table>

Values will differ by geographic location and should best be determined in the clinical setting where they are applied. For example, hazelnut values will perform differently in parts of Europe where birch pollen allergy is commonplace; this will also differ with the age of the patient. The action to be taken with each post test LR will differ between clinics and is influenced by local practice, the family’s preference, and the clinical scenario faced.
D: Oral Challenges: recommended doses

Table I-D Recommended incremental dosages for DBPCFC with milk, egg, peanut, wheat or soy

<table>
<thead>
<tr>
<th>Food protein (mg)</th>
<th>3mg</th>
<th>10 mg</th>
<th>30 mg</th>
<th>100 mg</th>
<th>300 mg</th>
<th>1000 mg</th>
<th>3000 mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasteurized cow’s milk with 3.3% protein content</td>
<td>90.9 mg ≈ 0.1 ml</td>
<td>303.0 mg ≈ 0.3 ml</td>
<td>909.0 mg ≈ 0.9 ml</td>
<td>3,030.3 mg ≈ 3.0 ml</td>
<td>9,090.9 mg ≈ 9.1 ml</td>
<td>30,303.0 mg ≈ 30.3 ml</td>
<td>90,909.1 mg ≈ 90.9 ml</td>
</tr>
<tr>
<td>Skim milk powder with 36% protein content</td>
<td>8.3 mg</td>
<td>27.8 mg</td>
<td>83.3 mg</td>
<td>277.8 mg</td>
<td>833.3 mg</td>
<td>2,777.8 mg</td>
<td>8,333.3 mg</td>
</tr>
<tr>
<td>Pasteurized whisked hen’s egg with 12.8% protein content</td>
<td>23.4 mg</td>
<td>78.1 mg</td>
<td>234.4 mg</td>
<td>781.3 mg</td>
<td>2,343.8 mg</td>
<td>7,812.5 mg</td>
<td>23,437.5 mg</td>
</tr>
<tr>
<td>Hen’s egg powder with 47% protein content</td>
<td>6.4 mg</td>
<td>21.3 mg</td>
<td>63.8 mg</td>
<td>212.8 mg</td>
<td>638.3 mg</td>
<td>2,127.7 mg</td>
<td>6,383.0 mg</td>
</tr>
<tr>
<td>Peanut butter with 24% protein content</td>
<td>12.5 mg</td>
<td>41.7 mg</td>
<td>125.0 mg</td>
<td>416.7 mg</td>
<td>1,250.0 mg</td>
<td>4,166.7 mg</td>
<td>12,500.0 mg</td>
</tr>
<tr>
<td>Peanut flour with 50% protein content</td>
<td>6.0 mg</td>
<td>20.0 mg</td>
<td>60.0 mg</td>
<td>200.0 mg</td>
<td>600.0 mg</td>
<td>2,000.0 mg</td>
<td>6,000.0 mg</td>
</tr>
<tr>
<td>Gluten powder with 80% protein content</td>
<td>3.8 mg</td>
<td>12.5 mg</td>
<td>37.5 mg</td>
<td>125.0 mg</td>
<td>375.0 mg</td>
<td>1,250.0 mg</td>
<td>3,750.0 mg</td>
</tr>
<tr>
<td>Soy drink with 3.3% protein content</td>
<td>90.9 mg ≈ 0.1 ml</td>
<td>303.0 mg ≈ 0.3 ml</td>
<td>909.0 mg ≈ 0.9 ml</td>
<td>3,030.3 mg ≈ 3.0 ml</td>
<td>9,090.9 mg ≈ 9.1 ml</td>
<td>30,303.0 mg ≈ 30.3 ml</td>
<td>90,909.1 mg ≈ 90.9 ml</td>
</tr>
<tr>
<td>Soy powder with 50% protein content</td>
<td>6.0 mg</td>
<td>20.0 mg</td>
<td>60.0 mg</td>
<td>200.0 mg</td>
<td>600.0 mg</td>
<td>2,000.0 mg</td>
<td>6,000.0 mg</td>
</tr>
</tbody>
</table>

E: Component resolved IgE studies included in the systematic review

<table>
<thead>
<tr>
<th>Target food</th>
<th>Component specific IgE</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hen’s egg</td>
<td>Gal d 1, Gal d 2, Gal d 3, Gal d 5</td>
<td>(93)</td>
</tr>
<tr>
<td>Shrimp</td>
<td>Pen a 1</td>
<td>(44)</td>
</tr>
<tr>
<td>Peanut</td>
<td>Ara h 1, Ara h 2, Ara h 3, Ara h 8, Ara h 9</td>
<td>(29)</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>Cor a 1, Bet v 1, Bet v 2, Cor a 8</td>
<td>(94)</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>Cor a 9 and Cor a 14</td>
<td>(95)</td>
</tr>
<tr>
<td>Carrot</td>
<td>Bet v 1, Bet v 2, Bet v 6</td>
<td>(96)</td>
</tr>
<tr>
<td>Celery</td>
<td>Bet v 1, Bet v 2</td>
<td>(97)</td>
</tr>
<tr>
<td>Courgette</td>
<td>Bet v 1, Bet v 2</td>
<td>(98)</td>
</tr>
</tbody>
</table>
## Appendix II: Diagnosis - barriers and facilitators to implementation, audit criteria and resource implications of recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PATIENT’S CLINICAL HISTORY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detailed clinical history is essential for the diagnosis of food allergy. When taking a clinical history eliciting allergens, timing and chronicity, symptoms, severity and signs, reproducibility, known risk (co)factors, family history, co-existing medical problems including other allergic diseases should be addressed. The use of structured questions on symptoms, foods and other background information is recommended</td>
<td>IV</td>
<td>C</td>
<td>Lack of standardized questionnaire Training of health professionals</td>
<td>Development of standardized questionnaire Training of health professionals</td>
<td>% of patients where diagnosis excluded on the basis of clinical history</td>
</tr>
<tr>
<td><strong>DETERMINATION OF SENSITIZATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IgE sensitization does not always result in clinical relevant food allergy, therefore, specific allergy testing should be directed by case history.</td>
<td>IV</td>
<td>C</td>
<td>Health professionals attitudes Poor access to allergy consultation Lack of public information</td>
<td>Specific education of healthcare professionals Improved access to allergy consultation Improved information to the public</td>
<td>% of patients properly diagnosed with food allergy</td>
</tr>
<tr>
<td>SPT and/or sIgE can be the test of choice depending on local availability and absolute and relative contraindications to SPT.</td>
<td>IV</td>
<td>C</td>
<td>Lack of facilities and poor access to allergy consultation</td>
<td>Improvement of access to allergy testing Improvement of access to allergy training of primary care physicians</td>
<td>Increase in allergy testing Increase of facilities for allergy testing</td>
</tr>
<tr>
<td>IgE sensitization to common food allergens is determined by SPT and serum IgE tests and is used as a support to the diagnosis of food allergy by clinical history and/or food challenge. These tests are highly sensitive (75-100%). However, specificity of these tests is moderate (40-70%) and does not replace clinical history and food challenges. Where available, standardized tests and procedures should be used. In the presence of a suggestive history, a negative SPT or sIgE needs to be interpreted with caution particularly as these are expected in non-IgE mediated food allergy</td>
<td>I-III*</td>
<td>A-C*</td>
<td>Health professionals attitudes Poor access to allergy consultation Lack of public information</td>
<td>Specific education of healthcare professionals Improved access to allergy consultation Improved information to the public</td>
<td>% of patients properly diagnosed with food allergy</td>
</tr>
<tr>
<td>In case SPT and sIgE tests are inconclusive CRD (if available) provides additional information.</td>
<td>I – IV*</td>
<td>A – C*</td>
<td>Lack of facilities Difficulty in interpreting Costs</td>
<td>Increase in availability of CRD testing Training of healthcare professionals Reimbursement policies</td>
<td>% of patients properly diagnosed with CRD testing</td>
</tr>
<tr>
<td>Recommendation</td>
<td>Evidence level</td>
<td>Grade</td>
<td>Barriers to implementation</td>
<td>Facilitators to implementation</td>
<td>Audit criteria</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
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<td>----------------------------</td>
<td>--------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>If clinical history with SPT and/or sIgE is not highly predictive, a provocation test is required. Determination of total IgE is particularly useful in patients with severe eczema who often show very high total IgE levels which indicates that positive specific IgE results should be interpreted with care.</td>
<td>IV</td>
<td>C</td>
<td>Health professionals attitudes Poor access to allergy consultation Lack of public information</td>
<td>Specific education of healthcare professionals Improved access to allergy consultation Improved information to the public</td>
<td>% of patients properly diagnosed with food allergy</td>
</tr>
<tr>
<td>BAT and determination of sIgE to linear epitopes are promising techniques, which should be further studied.</td>
<td>V</td>
<td>D</td>
<td>Cost</td>
<td>Reduction of costs Research projects</td>
<td>Large cohort trials in patients with food allergy</td>
</tr>
</tbody>
</table>

**ELIMINATION DIETS FOR DIAGNOSTIC PURPOSES**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The determination of the foods to be avoided should be based on the allergy-focused diet history, clinical history and adjunct allergy testing, i.e. SPTs and/or sIgE determination.</td>
<td>V</td>
<td>D</td>
<td>Health professionals attitudes Poor access to allergy consultation Lack of public information</td>
<td>Specific education of healthcare professionals Improved access to allergy consultation Improved information to the public</td>
<td>% of patients properly diagnosed with food allergy</td>
</tr>
<tr>
<td>For all of the individually avoided foods the results of the diagnostic elimination diet should be carefully monitored and evaluated for 2-4 weeks of avoidance.</td>
<td>V</td>
<td>D</td>
<td>Lack of consultation with dieticians with competence in food allergy</td>
<td>Training of dieticians in food allergy</td>
<td>Increase in % of dieticians with competence in food allergy</td>
</tr>
<tr>
<td>In case the elimination diet leads to a significant relief of symptoms, it should be continued until the provocation test is performed. If no significant reduction of symptoms is obtained by elimination diet, the respective food allergy is highly unlikely. After the exclusion of confounding factors foods should be reintroduced into the diet after 2-4 weeks.</td>
<td>V</td>
<td>D</td>
<td>Health professionals attitudes Poor access to allergy consultation Lack of public information</td>
<td>Specific education of healthcare professionals Improved access to allergy consultation Improved information to the public</td>
<td>% of patients properly diagnosed with food allergy</td>
</tr>
</tbody>
</table>

**ORAL CHALLENGE TESTS**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>The oral food challenge (particularly the double-blind placebo-controlled food challenge) is the gold standard investigation for the objective diagnosis of IgE-and non-IgE mediated food allergy.</td>
<td>IV</td>
<td>D</td>
<td>Health professionals attitudes Poor access to allergy consultation and lack of allergy services Lack of public information Reimbursement policies</td>
<td>Specific education of healthcare professionals Improved access to allergy consultation Improved information to the public Proper reimbursement from national health systems and Insurance bodies</td>
<td>National guidelines for food allergy. Increase in number of OFC performed Development of policies within the context of the public health approach</td>
</tr>
<tr>
<td>Recommendation</td>
<td>Evidence level</td>
<td>Grade</td>
<td>Barriers to implementation</td>
<td>Facilitators to implementation</td>
<td>Audit criteria</td>
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<tr>
<td>There are many OFC designs available: standardized procedures should be used in order to achieve a safe and objective challenge outcome that is patient/research specific. OFC’s should be performed in patients who have an equivocal diagnosis of food allergy.</td>
<td>IV</td>
<td>D</td>
<td>Lack of information among healthcare professionals</td>
<td>Diffusion of proper information Training of health professional</td>
<td>% of patients properly diagnosed with food allergy</td>
</tr>
<tr>
<td>OFC’s should be used to demonstrate allergy or tolerance and in so doing facilitate safe dietary expansion or appropriate allergen avoidance.</td>
<td>IV</td>
<td>D</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>The OFC may be performed as an open, single or double-blinded challenge; variables such as clinical history, food allergen, patient criteria (age, concomitant food and other allergic disease, anxiety...), and research criteria should guide the selection of the OFC.</td>
<td>IV</td>
<td>D</td>
<td>Lack of information among healthcare professionals Lack of training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The OFC, in additional to establishing a firm diagnosis can be used to determine threshold reactivity, response to OIT, spontaneous resolution of food allergy and the exclusion of food allergy.</td>
<td>IV</td>
<td>D</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>The DBPCFC should be performed in the following settings: when symptoms are subjective, with delayed or atypical symptoms, where patients and/or caregivers are anxious, and considered in all research settings.</td>
<td>IV</td>
<td>D</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>A negative DBPCFC should end with an open or cumulative ingestion of the food to confirm oral tolerance.</td>
<td>IV</td>
<td>D</td>
<td></td>
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</tr>
<tr>
<td>OFC are not without risk, and must be performed in a specialist setting with emergency support immediately available. In patients with a moderate to high risk of a severe reaction, intensive care support must be immediately available.</td>
<td>IV</td>
<td>D</td>
<td></td>
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</tbody>
</table>

**UNCONVENTIONAL TESTS (INCLUDING SPECIFIC IgG TESTING)**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are no unconventional approaches which can be recommended as alternative or complementary diagnostic tools in the work up of suspected food allergy, and their use should be discouraged.</td>
<td>III</td>
<td>C</td>
<td>Miss information among the public Poor access to allergy consultation</td>
<td>Patient Organisations Counteraction of “myths”</td>
<td>Reduction in % of patients undertaking unconventional testing</td>
</tr>
</tbody>
</table>

*Range of levels of evidence and grades are due to range of different foods tested*
**APPENDIX II:** Management – barriers and facilitators to implementation, audit criteria and resource implications of recommendations.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACUTE MANAGEMENT</strong></td>
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</tr>
<tr>
<td>The patient at risk of severe reactions should be properly and timely identified.</td>
<td>IV</td>
<td>D</td>
<td>Lack of epidemiological data of inter and intra individual risk factors</td>
<td>Improved knowledge of mechanisms underlying severity an allergic reaction</td>
<td>Surveillance epidemiological studies of acute episodes Large multi-centred trials evaluating biomarkers in patients with severe reactions</td>
</tr>
<tr>
<td><strong>ANTIHISTAMINES AND MAST CELL STABILIZERS</strong></td>
<td></td>
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</tr>
<tr>
<td>There is evidence to support the benefits of antihistamines for children and adults with acute non-life threatening symptoms from food allergy.</td>
<td>III</td>
<td>C</td>
<td>Health professional attitude Lack of public information</td>
<td>Education</td>
<td>Reduction of % of patients with anaphylaxis using antihistamines</td>
</tr>
<tr>
<td>The prophylactic application of antihistamines is not recommended</td>
<td>V</td>
<td>D</td>
<td>Health professional attitude</td>
<td>Specific education of health professionals</td>
<td>Reduction of % of patients with anaphylaxis using antihistamines</td>
</tr>
<tr>
<td>Mast cell stabilisers are not recommended for the prophylactic treatment of food allergy.</td>
<td>III</td>
<td>C</td>
<td>Health professional attitude</td>
<td>Specific education of health professional</td>
<td>Reduction of % of patients with anaphylaxis using antihistamines</td>
</tr>
<tr>
<td><strong>ELIMINATION DIET</strong></td>
<td></td>
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<tr>
<td>A sufficient elimination diet should be based on a proper allergy diagnosis identifying the food allergen(s) responsible of the patient’s symptoms /reactions. The indications should be re-evaluated at appropriate intervals.</td>
<td>IV</td>
<td>D</td>
<td>Lack of proper allergy diagnosis Lack of compliance</td>
<td>Access to allergy services Counselling with proper attractive menus, patients and family</td>
<td>Increase in allergy services</td>
</tr>
<tr>
<td>Appropriate avoidance diets are the key treatment in the management of food allergy.</td>
<td>IV</td>
<td>D</td>
<td>Costs of alternative foods Difficulty in finding alternative foods Monotonous diet and difficulty in finding a pleasant replacement</td>
<td>Pleasant food options Psychological counselling</td>
<td>Availability of special food for allergic consumer on the market Increase in quality of life in patients who receive psychological counselling</td>
</tr>
<tr>
<td>Patients with food allergy who are on long term elimination diets should have access to appropriate nutritional counseling, ideally by a dietitian with competencies in food allergy, and regular monitoring of growth.</td>
<td>IV</td>
<td>C</td>
<td>Lack of appropriately trained dietitian with competencies in food allergy</td>
<td>Education of food allergy among dietitian’s training</td>
<td>% of patients with dietary compromises while on an elimination diet</td>
</tr>
<tr>
<td>Recommendation</td>
<td>Evidence level</td>
<td>Grade</td>
<td>Barriers to implementation</td>
<td>Facilitators to implementation</td>
<td>Audit criteria</td>
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<tr>
<td>Extensively hydrolysed cow’s milk formulas with documented hypoallergenicity can be recommended as first choice for the treatment of cow’s milk allergy, especially in infants and young children. Amino acid formulas can be recommended as well especially for a subgroup of patients with more severe symptoms.</td>
<td>I</td>
<td>A</td>
<td>Cost of the alternative formulas</td>
<td>Reduction of the costs</td>
<td>% of children with cow’s milk allergy who receive first choice formulas</td>
</tr>
<tr>
<td>Soy formulas should not be recommended before 6 months of age and at any age in the presence of gastrointestinal symptoms. From 6-12 months it can be considered on a case-by-case basis.</td>
<td>I</td>
<td>B</td>
<td>Health professional attitudes Costs in developing countries</td>
<td>Education</td>
<td>Reduction of the costs</td>
</tr>
<tr>
<td>Currently, probiotic supplements cannot be recommended for the management of food allergy</td>
<td>I</td>
<td>D</td>
<td>Public and health professionals attitudes Lack of evidence based benefit in large cohort studies</td>
<td>Awareness of the results of currently available studies</td>
<td>Large cohort studies to provide evidence based conclusions</td>
</tr>
</tbody>
</table>

**EDUCATION AND RISK ASSESSMENT**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients and caregivers need to be informed about the foods that should be avoided, and practical advice given on avoidance measures, how to recognize a further reaction and the self-management of these reactions.</td>
<td>V</td>
<td>D</td>
<td>Lack of awareness among health professionals</td>
<td>Allergy nurses and dieticians with competencies in food allergies patient organisations</td>
<td>% of patients joining patients organisations</td>
</tr>
<tr>
<td>Patients/carers should be encouraged to join an appropriate patient support organization.</td>
<td>V</td>
<td>D</td>
<td>Lack of relevant patient organisations Denial of having a disease requiring external support.</td>
<td>Establishment of patients’ organisations where needed Distribution of information of the activities of patient organisations at allergic clinics</td>
<td>% of patients attending training courses</td>
</tr>
<tr>
<td>All patients with food allergy require a management plan with appropriate education for the patient, caregiver including school.</td>
<td>V</td>
<td>D</td>
<td>Lack of standardized management plans</td>
<td>Standardized training courses to educate patients caregivers and schools Reimbursement policies for training courses</td>
<td>% of patients attending the ED</td>
</tr>
</tbody>
</table>

EAACI food allergy guidelines
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education should cover allergen avoidance, symptom recognition and indication for specific treatment and administration of specific medication.</td>
<td>V</td>
<td>D</td>
<td>Lack of knowledge and skills among parents, schools and professionals in recognizing symptoms</td>
<td>Written plans Educational courses Training courses</td>
<td>National and international policies for education within the context of a public health approach</td>
</tr>
<tr>
<td>Absolute indications with adrenaline auto-injector include previous anaphylaxis to any food, persistent or severe asthma, exercise induced food dependent anaphylaxis, and mastocytosis.</td>
<td>IV</td>
<td>C</td>
<td>Scarce knowledge among health professionals about proper management of severe allergic reactions Costs of self injectable devices Reimbursement policies</td>
<td>Development of tools for the management of severe reactions (i.e. on-line training courses, leaflets) to facilitate education of health professionals.</td>
<td>% of patients suffering from severe reactions prescribed with AAI % of patients with anaphylaxis who present to the ED having already used AAI Reduction of costs of AAI Improvement of reimbursement policies</td>
</tr>
<tr>
<td>Relative indications for adrenaline auto-injector with food allergy include (1) food allergies that are likely to be persistent; (2) mild-to-moderate allergic reaction to peanut and/or tree nut (3) mild-to-moderate reaction to very small amounts of food and (4) specific high risk groups, e.g. adolescents, young adult males, poor access to medical care.</td>
<td>IV-V*</td>
<td>C-D*</td>
<td>Scarce knowledge among health professionals about proper management of severe allergic reactions Costs of self injectable devices Reimbursement policies</td>
<td>Development of tools for the management of severe reactions (i.e. on-line training courses, leaflets) to facilitate education of health professionals.</td>
<td>% of patients suffering from severe reactions prescribed with AAI % of patients with anaphylaxis who present to the ED having already used AAI Reduction of costs of AAI Improvement of reimbursement policies</td>
</tr>
<tr>
<td>Adrenaline should be immediately administered for cardiovascular symptoms and/or respiratory symptoms such as altered voice, stridor or bronchospasm that is thought to be induced by food allergy.</td>
<td>IV</td>
<td>C</td>
<td>Scarce knowledge among health professionals about proper management of severe allergic reactions</td>
<td>Development of tools for the management of severe reactions (i.e. on-line training courses, leaflets) to facilitate education of health professionals. Written plans</td>
<td>Reduction of deaths due to anaphylaxis Surveillance epidemiological programmes</td>
</tr>
<tr>
<td>Short acting beta agonists should be included in the management plan for all patients with co-existing asthma and should be administered for bronchospasm after adrenaline has been administered.</td>
<td>V</td>
<td>D</td>
<td>Scarce knowledge among health professionals about proper management of severe allergic reactions</td>
<td>Development of tools for the management of severe reactions (i.e. on-line training courses, leaflets) to facilitate education of health professionals. Written plans</td>
<td>Reduction of deaths due to anaphylaxis Surveillance epidemiological programmes</td>
</tr>
<tr>
<td>Recommendation</td>
<td>Evidence level</td>
<td>Grade</td>
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<td>Barriers to implementation</td>
<td>Audit criteria</td>
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</tr>
<tr>
<td>Patient held glucocorticosteroids may be given with reactions to possibly prevent late phase respiratory symptoms.</td>
<td>V</td>
<td>D</td>
<td>Often used as first line treatment</td>
<td>Emphasis on adrenaline as first line treatment</td>
<td>Compare outcomes of anaphylaxis in patients who received adrenaline treatment with and without glucocorticosteroids</td>
</tr>
<tr>
<td>Any patient who has received adrenaline should be reviewed in an emergency department.</td>
<td>III</td>
<td>C</td>
<td>Lack of proper information from the patient</td>
<td>Education</td>
<td>% of patients presenting at ED after having been administered self-injectable adrenaline</td>
</tr>
<tr>
<td><strong>SPECIFIC IMMUNOTHERAPY</strong></td>
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</tr>
<tr>
<td>Food allergen-specific immunotherapy for primary food allergy is a promising immune-modulatory treatment approach (I), but it is associated with risk of adverse reactions, including anaphylaxis (I); it is therefore not at present recommended for routine clinical use.</td>
<td>III</td>
<td>C</td>
<td>Lack of established requirements for centres performing food allergen specific immunotherapy</td>
<td>Identification of criteria for centres of excellence</td>
<td>Increase in large multi-centre trials for food allergen immunotherapy</td>
</tr>
<tr>
<td>Immunotherapy in patients with respiratory symptoms /allergy to inhalant allergens that may also cause cross reactive food allergy, specific immunotherapy is recommended for the treatment for the respiratory symptoms but currently not for the primary treatment of cross-reactive food allergy.</td>
<td>IV</td>
<td>D</td>
<td>Lack of established requirements for centres performing food allergen specific immunotherapy</td>
<td>Identification of criteria for centres of excellence</td>
<td>Increase in large multi-centre trials for food allergen immunotherapy</td>
</tr>
<tr>
<td><strong>ANTI-IgE</strong></td>
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</tr>
<tr>
<td>The use of anti-IgE alone or in combination with specific immunotherapy is currently not recommended for the treatment of food allergy even though it represents a promising modality.</td>
<td>IV</td>
<td>D</td>
<td>Health professionals’ attitude</td>
<td>Identification of criteria for centres of excellence</td>
<td>Increase in large multi-centre trials for anti-IgE immunotherapy</td>
</tr>
<tr>
<td><strong>CHALLENGES AT REGULAR INTERVALS TO ASSESS ACHIEVEMENTS OF TOLERANCE</strong></td>
<td></td>
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</tr>
<tr>
<td>OFC should be performed at regularly intervals appropriate for the specific food and patients history in order to assess achievement of tolerance.</td>
<td>V</td>
<td>D</td>
<td>A lack of allergy services</td>
<td>Access to allergy services</td>
<td>Increase in number of OFC</td>
</tr>
<tr>
<td>Specific IgE tests (in vitro and skin-prick-test) are currently of little value in guiding adequately the timing of oral food challenges for development of tolerance.</td>
<td>V</td>
<td>D</td>
<td>Knowledge among health professionals</td>
<td>Education of health professionals</td>
<td>Survey of ongoing management of patients with food allergy</td>
</tr>
</tbody>
</table>
## COFACTORS

In food allergic reactions, the potential augmenting role of co-factors, i.e. such as exercise, NSAID, omeprazol or alcohol intake, should be assessed in a structured history.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>In food allergic reactions, the potential augmenting role of co-factors, i.e. such as exercise, NSAID, omeprazol or alcohol intake, should be assessed in a structured history.</td>
<td>III-IV**</td>
<td>D</td>
<td>Lack of standardized questionnaires</td>
<td>Development of properly designed questionnaires</td>
<td>Large surveillance programmes on incidence and prevalence of co-factors % of co-factors identified in patients suffering for severe reactions</td>
</tr>
<tr>
<td>In allergic reactions occurring after exercise, NSAID or alcohol intake, underlying food allergy to foods consumed in the previous hours should be assessed (especially gliadin sensitization or LTP in southern Europe).</td>
<td>IV</td>
<td>D</td>
<td>Lack of standardized questionnaires</td>
<td>Development of properly designed questionnaires</td>
<td>Large surveillance programmes on incidence and prevalence of co-factors % of co-factors identified in patients suffering for severe reactions</td>
</tr>
</tbody>
</table>

*Range of levels of evidence and grades are due to range of indications.

**Range of levels of evidence and grades are due to range of different cofactors.
SECTION 2

PRIMARY PREVENTION OF FOOD ALLERGY
2.1 PRIMARY PREVENTION OF FOOD ALLERGY IN CHILDREN AND ADULTS

SYSTEMATIC REVIEW

D de Silva¹, M Geromi¹, S Halken², A Host², SS Panesar³, A Muraro⁴, T Werfel⁵, K Hoffmann-Sommergruber⁶, G Roberts⁷-⁹, V Cardona¹⁰, AEJ Dubois¹¹, LK Poulsen¹², R van Ree¹³, B Vlieg–Boerstra¹⁴, I Agache¹⁵, K Grimshaw⁹, L O’Mahony¹⁶, C Venter¹⁷, S. H. Arshad⁷-⁹, A Sheikh³,¹⁸, on behalf of the EAACI Food Allergy and Anaphylaxis Group

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16 Swiss Institute of Allergy and Asthma Research, University of Zurich, Davos, Switzerland
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18 Division of General Internal Medicine and Primary Care, Brigham and Women’s Hospital/Harvard Medical School, Boston, USA
Background: Food allergies can have serious physical, social and financial consequences. This systematic review examined ways to prevent the development of food allergy in children and adults.

Methods: Seven bibliographic databases were searched from their inception to September 30, 2012 for systematic reviews, randomized controlled trials, quasi-randomized controlled trials, controlled clinical trials, controlled before-and-after studies, interrupted time series and cohort studies. Experts were consulted for additional studies. There were no language or geographic restrictions. Two reviewers appraised the studies using appropriate tools. Data were not suitable for meta-analysis due to heterogeneity so were narratively synthesized.

Results: Seventy-four studies were included; one third of which were of high quality. There was no good evidence to recommend that pregnant or breastfeeding women should change their diet or take supplements to prevent allergies in infants at high or normal risk. There were mixed findings about the preventive benefits of breastfeeding for infants at high or normal risk, but there was evidence to recommend avoiding cow’s milk and substituting with extensively or partially hydrolyzed whey or casein formulas for infants at high risk for the first four months. Soy milk and delaying the introduction of solid foods beyond four months did not have preventive benefits in those at high or normal risk. There was very little evidence about strategies for preventing food allergy in older children or adults.

Conclusions: There is much to learn about preventing food allergy and this is a priority given the high societal and healthcare costs involved.

Background
People with food allergies suffer symptoms that affect both their health and lifestyle so there is considerable interest in ways to reduce the risk of developing a food allergy. The causes of food allergy are likely related to both genetic factors and environmental exposure (1, 2). Genetic factors are not modifiable so strategies to prevent food allergy have focused on limiting early exposure to potential allergens antenatally or during breastfeeding, by changing what mothers eat in the hope that this will limit allergen exposure to their babies or boost protective mechanisms (3, 4). Prevention strategies may also directly target the infant formula and foods that babies and children consume (5). This review summarizes evidence about the most effective ways to prevent food allergy in children and adults.

This systematic review is one of seven inter-linked syntheses undertaken to provide a state-of-the-art synopsis of the evidence base in relation to the epidemiology, prevention, diagnosis, management, and impact on quality of life. This will be used to inform clinical recommendations in the European Academy of Allergy and Clinical Immunology (EAACI) Guidelines for Food Allergy and Anaphylaxis.

Methods
Protocol and registration
The review was registered with the International Prospective Register of Systematic Reviews. The protocol has been published previously (6) so only brief details about the methodology are provided here.

Search strategy
The following databases were searched: Cochrane Library; Medline, Embase, CINAHL, ISI Web of Science, TRIP Database and Clinicaltrials.gov. Experts in the field were contacted for additional studies. Further details are included in the review protocol (6).

Inclusion and exclusion criteria
This review focused solely on studies that were primarily concerned with preventing sensitization to food(s) and/or the development of food allergy. Studies seeking to prevent potential manifestations of food allergy such as atopic eczema/dermatitis or asthma, but not including an explicit diagnosis of sensitization to food or food allergy, were not included.

Systematic reviews and meta-analyses, randomized controlled trials, quasi-randomized controlled trials, controlled clinical trials, controlled before-and-after studies, interrupted time series studies and prospective cohort studies published up until September 30, 2012 were eligible. No language restrictions were applied and, where possible, relevant studies in languages other than English were translated.

Study selection
The titles and abstracts of articles were checked by two independent reviewers and categorized as included, not included and unsure (DdS and MG). Full text copies of potentially relevant studies were obtained and their eligibility for inclusion was independently assessed by two reviewers (DdS and MG). Any discrepancies were resolved by consensus or discussion with other reviewers (SH and AS).

Risk of bias assessment
Risk of bias was independently carried out by two reviewers (DdS and MG) using adapted versions of the Critical Appraisal Skills Programme (CASP) tool and the Cochrane Effective Practice and Organisation of Care Group (EPOC) Risk of Bias tools. An overall grading of high, medium or low quality was assigned to each study.

Analysis, synthesis and reporting
Two reviewers independently used a customized data extraction form to obtain data from each study (DdS and MG). Discrepancies were resolved by discussion. Experts in the field checked all of the data extraction for accuracy and relevance (SH and AH). Meta-analysis was not appropriate because the studies were heterogeneous in focus, design, target populations and interventions. Findings were synthesized narratively by grouping studies according to intervention and target population. These syntheses were checked by a group of methodologists and experts to ensure accuracy and relevance.

Results
Study selection and characteristics
Figure 1 shows the PRISMA flowchart. Seventy-four studies were included, comprising 15 systematic
reviews (20%), 32 randomized controlled trials (43%), nine non-randomized comparative studies (12%) and 19 cohort studies (25%). Based on the risk of bias assessment, 25 of the studies were deemed to be of high quality (34%), 19 were of moderate quality (26%) and 30 were of low quality (40%), often due to small sample sizes or non-randomized designs. Further details about each study are available in the online supplement.

Most studies focused on preventing the development of food allergy from an early age (i.e. in unborn children and infants). Many studies focused on babies at high risk due to having a family history of allergy or atopy. Throughout the review, the term ‘at high risk’ is used as an abbreviation to mean that infants had an increased risk of developing food allergy or atopy due to a familial history of allergic disease

Table 1 summarizes the key findings.

Prevention strategies in pregnant women

High-risk families

Unborn children may be sensitized to the foods their mothers’ consume (7, 8). Investigations have therefore been undertaken to establish whether avoiding particularly allergenic foods during pregnancy has an impact on the development of food allergy in their offspring, but the answer remains unclear. A systematic review (9) and two randomized controlled trials found no benefit from restricting common food allergens among pregnant women (10, 11).

Supplements to modulate the developing immune system are another approach that has received interest. Fish oil supplements may be worthy of further investigation because two randomized controlled trials suggested trends towards reduced sensitization to egg (12, 13), although there was no beneficial impact demonstrated on the development of food allergy (14).
## Table 1 Summary of key evidence about prevention strategies

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Studies (% high quality)</th>
<th>Findings about preventive effects in those at high risk</th>
<th>Findings for normal risk or unselected populations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANTENATAL STRATEGIES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal diet</td>
<td>5 (20%)</td>
<td>One systematic review (9) and two randomised trials (10, 11) found <strong>no benefit</strong>.</td>
<td>One study with results from two cohort studies found that different aspects of maternal diet may be associated with an <strong>increased risk</strong> of food allergy. High maternal celery and citrus fruit intake increased sensitization to food in infants (16, 17).</td>
</tr>
<tr>
<td>Maternal fish oil supplements</td>
<td>2 (50%)</td>
<td>Two randomised trials suggested a <strong>preventive effect</strong> against egg sensitization (12, 13).</td>
<td></td>
</tr>
<tr>
<td>Maternal probiotic supplements</td>
<td>1 (100%)</td>
<td>One randomised trial found a <strong>benefit</strong> for sensitization, but was inconclusive overall (15).</td>
<td></td>
</tr>
<tr>
<td><strong>STRATEGIES TARGETING BREASTFEEDING MOTHERS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diet when breastfeeding</td>
<td>2 (0%)</td>
<td>Two non-randomised comparisons found <strong>no evidence</strong> of a protective effect for food allergy (20, 21).</td>
<td>One systematic review (23) and two randomised trials found <strong>no good evidence of a benefit</strong> (24, 25).</td>
</tr>
<tr>
<td>Probiotics when breastfeeding</td>
<td>1 (100%)</td>
<td>One randomised trial found <strong>no protective effect</strong> (22).</td>
<td></td>
</tr>
<tr>
<td>Fish oil when breastfeeding</td>
<td>3 (67%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STRATEGIES TARGETING INFANTS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breastfeeding</td>
<td>11 (9%)</td>
<td>One systematic review found that most studies of breastfeeding in those at high risk identified a protective <strong>benefit</strong> (1). Two cohort studies suggested no benefit and that exclusively breastfeeding may even increase the risk of food allergy (28, 29).</td>
<td>One systematic review (1) and three cohort studies found that breastfeeding was associated with a <strong>reduced risk</strong> of sensitization or food allergy (58-60), three cohort studies suggested an increased risk (61-63) and three cohorts found no association (64-66).</td>
</tr>
<tr>
<td>Alternatives to cows’ milk formula</td>
<td>18 (44%)</td>
<td>Two systematic reviews and four randomised trials found a <strong>benefit</strong> from extensively hydrolysed whey or casein formula, (1, 30-33) though one study found no benefit (34). Two systematic reviews two randomised trials and two non-randomised comparisons found a <strong>benefit</strong> from partially hydrolysed formula compared to cows’ milk formula (36-41). One randomised trial and one non-randomised study found no effect (34, 35). One systematic review (36) and two randomised trials found no benefit from soy-based formula (43, 44).</td>
<td></td>
</tr>
<tr>
<td>Infant prebiotic supplements</td>
<td>2 (50%)</td>
<td></td>
<td>One systematic review found <strong>insufficient evidence</strong> (67) and one trial found no benefits (68).</td>
</tr>
<tr>
<td>Infant probiotic supplements</td>
<td>7 (86%)</td>
<td>Four trials found <strong>no evidence of a benefit</strong> (45-48).</td>
<td>Two systematic reviews (69, 70) and one trial (71) found <strong>no evidence of a benefit</strong>.</td>
</tr>
</tbody>
</table>
Strategies for Older Children and Adults

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Studies (% high quality)</th>
<th>Findings about preventive effects in those at high risk</th>
<th>Findings for normal risk or unselected populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccinations</td>
<td>1 (100%)</td>
<td></td>
<td>One systematic review found that BCG vaccinations had no protective effect against food allergy (80).</td>
</tr>
<tr>
<td>Supplements</td>
<td>2 (50%)</td>
<td></td>
<td>One review found no benefit from fish oil supplements (81). One cohort study found that taking vitamins before age five may protect against food allergy (82).</td>
</tr>
</tbody>
</table>

There was insufficient evidence about probiotics, with just one inconclusive trial identified about this (15).

Normal-risk families
In unselected populations, one study with results from two cohort studies suggested that what women eat during pregnancy may impact on food sensitization in infants. High maternal celery and citrus fruit intake increased infant sensitization to food (16, 17) but these studies have not been replicated and did not focus on allergy development so there is no strong evidence to recommend changes to the diet of pregnant women to prevent food allergy in infants.

Prevention strategies for breastfeeding mothers

High-risk families
It has been hypothesized that mothers may inadvertently sensitize their children to certain foods through breast milk (18, 19), but there is little evidence that changing what mothers consume when breastfeeding prevents food allergy in infants. Two non-randomized comparisons found that maternal dietary changes while breastfeeding may not prevent food allergies in high-risk infants (20, 21), and one

Table 1 (continued)

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Studies (% high quality)</th>
<th>Findings about preventive effects in those at high risk</th>
<th>Findings for normal risk or unselected populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other supplements</td>
<td>2 (0%)</td>
<td></td>
<td>One trial and one cohort study found no evidence to recommend other supplements (72, 73).</td>
</tr>
<tr>
<td>Age at introduction of solid foods</td>
<td>7 (14%)</td>
<td>Two cohort studies found no benefit from delaying the introduction of solid foods longer than four months (49, 50).</td>
<td>One systematic review (17) and two cohort studies found no benefit of delaying the introduction of solid foods longer than four months (17, 75). Two cohort studies found reduced food allergy when solids were introduced earlier than four months (64, 76).</td>
</tr>
<tr>
<td>Exposure to food allergens</td>
<td>6 (33%)</td>
<td>One randomised trial found no benefit from withholding cows’ milk or foods made with cow’s milk during the first four months of infancy (51).</td>
<td>One systematic review and one trial found that exposure to cows’ milk protein the first days of life did not alter the risk, (66, 78) but one trial and one cohort suggested an increased risk of cows’ milk allergy (66, 78). One cohort study found that consumption of fish during infancy may protect against food allergy or sensitization (80).</td>
</tr>
<tr>
<td>Multifaceted strategies combining changes to environment and diet</td>
<td>9 (33%)</td>
<td>Two randomised trials, two non-randomised comparisons and one cohort study found a benefit from combining dietary and environmental strategies (53-57). Two systematic reviews found insufficient evidence to make firm recommendations about preventive strategies (83, 84).</td>
<td></td>
</tr>
</tbody>
</table>
Preventing food allergy: systematic review

Normal-risk families

One systematic review (23) and two randomized controlled trials (24, 25) found no differences in most infant allergy outcomes from fish oil supplements taken by unselected populations of breastfeeding women.

Prevention during infancy

High-risk families

More research has been published about preventive strategies targeting infants. Although breastfeeding is widely promoted and has many other benefits (26, 27), there is insufficient evidence to draw conclusions about its impact on preventing food allergies in high-risk infants. One systematic review identified many studies suggesting a benefit from exclusive and non-exclusive breastfeeding (1); in contrast, however, two cohort studies suggested that extended exclusive breastfeeding may increase the likelihood of sensitization or food allergy in infants at high risk (28, 29).

There is more positive evidence about the benefits of alternatives to cow’s milk formula for babies at high risk. Two systematic reviews and three randomized trials suggested that extensively hydrolyzed whey or casein formula may have a protective effect (1, 30-33) although the evidence was conflicting (34).

Partially hydrolyzed infant formula also appears to have a protective effect. Although a small number of studies failed to find any benefit (35), two systematic reviews, two randomized controlled trials and two non-randomized comparisons found that partially hydrolyzed formula may protect against food allergy compared with standard cow’s milk formula (36-41). There appeared to be little difference between whey- or casein-based formulations or between partially or extensively hydrolyzed formulas.

There was no evidence to support soy-based formulas. One systematic review (42) and two randomized trials (43, 44) found that soy-based formulas may not protect against food allergies compared to cow’s milk formula or other alternatives.

It is also unlikely that probiotic supplements confer preventive benefits during infancy. Four randomized controlled trials found no benefit for preventing food allergy or sensitization (45-48).

Another strategy is to delay the introduction of solid foods. Infants may not need, or may not be physiologically ready to eat, solid foods until after the age of four to six months, but two cohort studies found that delaying the introduction of solid foods longer than four months did not seem to confer any protective benefits (49, 50). Another cohort study found that avoiding cow’s milk or foods containing cow’s milk for four months had no impact (51).

Although the quality of evidence is low, there is some evidence from six studies to suggest that combining dietary with environmental modifications during infancy may be useful (52-57). Further research in this area is needed because there are few data about specific food allergy outcomes and it is difficult to differentiate cause and effect relationships.

Normal-risk families

The evidence about preventive strategies for infants in unselected populations or those at normal risk is also mixed. One systematic review (1) and three cohort studies found that breastfeeding was associated with a reduced risk of food allergy or sensitization in childhood (58-60), three cohort studies suggested an increased risk (61-63) and three cohort studies found no association in unselected populations (64-66).

There is no evidence to support prebiotics or probiotics to prevent food allergy in unselected or mixed-risk populations. One systematic review (67) found insufficient evidence and one trial found no benefits from prebiotics (68). Two systematic reviews (69, 70) and one randomized trial (71) found no benefit from probiotics in unselected or mixed populations. One randomized trial (72) and one cohort study found no evidence to recommend other supplements (73).

One systematic review (74) and two cohort studies found that introducing solid foods after four months did not protect against food allergy in unselected populations (17, 75). Two cohort studies found reduced food allergy when solids were introduced earlier than four months (64, 76).

Studies have investigated whether exposure to cow’s milk proteins in the first three days of life may protect against sensitization to foods. Two randomized controlled trials found that early exposure to cow’s milk protein did not alter the risk of food allergy (77, 78), but two cohort studies suggested an increased risk of cow’s milk allergy if children in unselected populations were fed cow’s milk protein early (28, 66).

There is little other evidence about avoiding potential...
food allergens, although one cohort study found that consuming fish during infancy may protect against food allergy or sensitization (79).

Prevention during childhood and adulthood
Very little has been published about strategies to prevent food allergy development in children and adults, and all available studies are in unselected populations. One systematic review found that BCG vaccinations for children had no protective effect against food allergy (80) and another systematic review found no protective benefit from fish oil supplements for children and adults (81). A cohort study found that taking vitamins before age five may protect against food allergy, but the quality of this type of evidence is low (82).

Discussion
Statement of principal findings
This comprehensive and rigorously undertaken review indicates that there is much still to learn about how to prevent the development of food allergy. Overall, the evidence is not strong enough to recommend changing the diet or supplements of pregnant or breastfeeding women at normal or high risk. While breastfeeding may have many other benefits, the evidence in relation to the prevention of food allergy is not strong. This to a large extent reflects the ethical challenges of randomizing infants to a non-breastfeeding arm. There is more evidence about the benefits of alternatives to cow’s milk formula for babies at high risk. Extensively hydrolyzed whey or casein formula and partially hydrolyzed formula may have a protective effect, but it appears that soy formula does not protect against food allergies. Probiotics do not seem to be protective in infants at high or normal risk, and neither does delaying the introduction of solid foods until later than the recommended minimum weaning age. Combining dietary with environmental modifications during infancy may be the best way forward for infants at high risk.

Strengths and limitations
This review included the most up to date research about preventing food allergy, with studies from Europe, North America, Asia and Australasia. It was conducted using stringent international standards and drew on a substantially greater evidence base than previous reviews (83, 84).

However, the studies included were heterogeneous, and as a result it was not appropriate to quantitatively synthesize this evidence. The inclusion criteria meant that studies about manifestations of food allergy such as atopic eczema, dermatitis and asthma were not included unless food allergy or sensitization was also studied as an outcome. Furthermore, due to the mixed findings and small evidence base, we were unable to draw conclusions about the comparative benefits and risks of different prevention approaches, or to quantify potential effects.

There are also limitations with the studies themselves. To date, the focus of research has largely been on preventing IgE-mediated food allergy rather than non-IgE-mediated food allergy. Many studies are small, short-term and focus on the surrogate measure of food sensitization rather than food allergy. Sensitization may be a normal, harmless and transitory phenomenon which does not necessarily correlate with allergic disease.

Another issue is the extent to which research provides meaningful information for clinical practice. For example, many infants and young children grow out of their food allergy, especially those who are allergic to cow’s milk protein during the first three to five years of life. To provide useful information, studies should include follow-ups from birth at regular intervals during the first years of life, as well as when the children have symptoms suggestive of food allergy. This would help to avoid claims that an intervention makes a difference when any change is merely a function of the natural course of the condition’s progression.

Conclusions
Finding ways to prevent the development of food allergy would significantly reduce morbidity and costs of managing this disorder (85). The evidence suggests that some interventions are unlikely to be useful, such as changing the diet or supplements of pregnant or breastfeeding women. However, other strategies appear more promising. There is evidence to support alternatives to cow’s milk formula for babies at high risk, although changes to infant diet such as delaying the introduction of solid foods are unlikely to protect against food allergy. Combining environmental with dietary changes is feasible, but there is much work to be done to identify the most effective strategies.
Acknowledgements

We would like to acknowledge the support of EAACI and the EAACI Food Allergy and Anaphylaxis Guidelines Group in developing this systematic review. We would also like to thank the EAACI Executive Committee for their suggestions.

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EAACI

Contributorship

AS, AM, DdS and GR conceived this review. The review was undertaken by DdS, MG and colleagues at The Evidence Centre. DdS led the drafting of the manuscript and all authors commented on drafts of the manuscript and agreed the final version. SH provided detailed feedback at each stage. This review was undertaken as part of a series managed by SSP and overseen by AS.

Conflicts of interest

K. Grimshaw has received payment for attending and presenting at conferences hosted by Nutricia Ltd. L.O’Mahony has been a consultant to Alimentary Health Ltd. C. Venter has produced educational material for Danone, Mead Johnson and Nestlé and has received research funding from Thermofischer, Danone and Mead Johnson. The other authors of the paper declare no conflict of interest.

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2.2 PRIMARY PREVENTION OF FOOD ALLERGY IN CHILDREN AND ADULTS

EAACI GUIDELINES

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Food allergy can have significant effects on morbidity and quality of life and can be costly in terms of medical visits and treatments. There is therefore considerable interest in generating efficient approaches that may reduce the risk of developing food allergy. These guidelines have been prepared by the European Academy of Allergy and Clinical Immunology’s (EAACI) Taskforce on Prevention and is part of the EAACI Guidelines for Food Allergy and Anaphylaxis. It aims to provide evidence-based recommendations for primary prevention of food allergy. A wide range of antenatal, perinatal, neonatal and childhood strategies were identified and their effectiveness assessed and synthesized in a systematic review.

Based on this evidence families can be provided with evidence-based advice about preventing food allergy, particularly for infants at high-risk for development of allergic disease. The advice for all mothers includes a normal diet without restrictions during pregnancy and lactation. For all infants exclusive breastfeeding is recommended for at least the first 4-6 months of life. If breastfeeding is insufficient or not possible, infants at high-risk can be recommended a hypoallergenic formula with a documented preventive effect for the first 4 months. There is no need to avoid introducing complementary foods beyond four months, and currently the evidence does not justify recommendations about either withholding or encouraging exposure to potentially allergenic foods after four months once weaning has commenced, irrespective of atopic heredity. There is no evidence to support the use of prebiotics or probiotics for food allergy prevention.

**Background**

Food allergy can have a significant effect on people’s morbidity and quality of life, and can be costly in terms of medical visits and treatments (Box 1). Given the morbidity resulting from food allergy, there is considerable scientific, professional and lay interest in approaches that may reduce the risk of developing food allergy. These guidelines have been prepared by the European Academy of Allergy and Clinical Immunology’s (EAACI) Taskforce on Prevention and is part of the EAACI Guidelines for Food Allergy and Anaphylaxis. These guidelines aim to provide evidence-based recommendations for the primary prevention of food allergy. The primary audience is allergists throughout Europe, but these guidelines are also likely to be of relevance to all other healthcare professionals (e.g. doctors, nurses and pharmacists) in hospitals’ primary care and other ambulatory settings.

The causes of food allergy are likely to reflect an interaction between genetic factors and environmental exposure. Genetic factors are currently not modifiable, so strategies to prevent food allergy have tended to focus on early likely exposures to the food proteins most likely to be involved in its pathogenesis. These strategies may be implemented before birth or during breastfeeding, by focusing on the maternal diet, or it may directly target infant nutrition. In addition, there has been a focus on other nutritional factors or supplements that may modify the immune system in a positive direction.

In these guidelines, primary prevention of food allergy is defined as prevention of development of food allergy. A wide range of antenatal, perinatal, neonatal and childhood strategies have been investigated, and the development of the guidelines have been informed by a systematic review of interventions for the primary prevention of food allergy in children and adults (1) (see Chapter 2.1). This systematic review includes only studies with food allergy or food sensitization as outcomes. In instances where there is a lack of clear or consistent evidence, the findings of the literature review have been supplemented with expert consensual opinion. Even though only studies where food allergy or food sensitization was an outcome were included, other possible atopic/allergic symptoms such as atopic dermatitis are also reported. Not all studies reported on confirmed food allergy or sensitization to foods, and some reported food allergy in a combined outcome with other allergies.

**Methods**

These guidelines were produced using the Appraisal of Guidelines for Research & Evaluation (AGREE II) approach (2, 3). This is a structured approach to guideline production that is designed to ensure appropriate representation of the full range of stakeholders, a careful search for and critical appraisal

**Box 1 Key terms**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>High risk</td>
<td>In the literature, this is defined as infants/children having at least one parent and/or sibling with a history of allergic disease sometimes also supplemented with an elevated cord blood IgE. Here, we have defined high-risk as having one or two parents and/or older siblings with a history of allergic disease (food allergy, atopic eczema/dermatitis, asthma or allergic rhinitis)</td>
</tr>
<tr>
<td>Unselected</td>
<td>Infants and children in an unselected population including families with and without allergic diseases i.e. low risk as well as high risk infants/children</td>
</tr>
<tr>
<td>Infancy</td>
<td>In the literature used to describe either first month or first year; here infancy is defined as the first year of life</td>
</tr>
<tr>
<td>Children</td>
<td>All age groups of children</td>
</tr>
<tr>
<td>Sensitization</td>
<td>A positive skin prick test (SPT) and/or detectable specific IgE (sIgE) irrespective of method or cut-off values and irrespective of clinical reactions</td>
</tr>
<tr>
<td>Food allergy</td>
<td>Adverse reaction to a food allergen caused by immunological mechanisms</td>
</tr>
<tr>
<td>Proven food allergy</td>
<td>Food allergy documented by controlled elimination / challenge procedures</td>
</tr>
<tr>
<td>Prebiotic</td>
<td>Non-digestible substances that provide a beneficial physiological effect for the host by selectively stimulating the favorable growth or activity of a limited number of indigenous bacteria</td>
</tr>
<tr>
<td>Probiotic</td>
<td>Live microorganisms which, when administered in adequate amounts, confer a health benefit on the host</td>
</tr>
</tbody>
</table>
of the relevant literature, a systematic approach to the formulation and presentation of recommendations, and steps to ensure that the risk of bias is minimized at each step of the process. We provide below an overview of the approach used.

**Clarifying the scope and purpose of the guidelines**

This process began in January 2012 with a meeting to discuss the overall approach to guideline development, including detailed discussions on the main aims of the guidelines, the target conditions, clarifying the target populations, to whom the recommendations applied, agreeing the intended end-user group, and ensuring adequate professional and lay representation in the guideline development process.

**Ensuring appropriate stakeholder involvement**

Participants represented a range of European countries, and disciplinary and clinical backgrounds (including medical secondary care, primary care and nursing), and patient groups. The Prevention Task Force continued to work together over the ensuing 18 months through email discussions, teleconferences and face-to-face meetings.

**Systematic review of the evidence**

The initial full range of questions that were considered important were rationalized through several rounds of iteration to agree to one key over-arching question (Box 2) that were then pursued through a formal protocol (4) to a systematic review of the evidence (1) (Chapter 2.1). Seven bibliographic databases were searched from their inception to September 30, 2012 for systematic reviews, randomized controlled trials, quasi-randomized controlled trials, controlled clinical trials, controlled before-and-after studies, interrupted time series and cohort studies. Cohort studies were included due to an inability to randomize with interventions such as breastfeeding. Excluded were reviews, discussion papers, non-research letters and editorials, qualitative studies, case studies, case series and animal studies.

**Formulating recommendations**

We graded the overall strength and consistency of the evidence to translate the key findings from the systematic review into evidence-linked recommendations (5) (Boxes 3, 4). This involved formulating clear recommendations and making clear the strength of evidence underpinning each recommendation. This ranged from consistent evidence derived from systematic reviews of randomized controlled trials through to evidence derived from expert consensus. Experts identified the resource implications of implementing the recommendations, barriers and facilitators to the implementation of each recommendation, advice on

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**Box 2**

Key over-arching question addressed in the supporting systematic reviews (4)

**What is the effectiveness of approaches for the primary prevention of food allergy?**

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**Box 3**

Assigning levels of evidence and recommendations (5)

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### LEVEL OF EVIDENCE

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>Systematic reviews, meta-analysis, randomized control trials</td>
</tr>
<tr>
<td>Level II</td>
<td>Two groups, non-randomized studies (e.g. cohort, case-control)</td>
</tr>
<tr>
<td>Level III</td>
<td>One-group non-randomized (e.g. before and after, pre test and post test)</td>
</tr>
<tr>
<td>Level IV</td>
<td>Descriptive studies that include analysis of outcomes (single-subject design, case-series)</td>
</tr>
<tr>
<td>Level V</td>
<td>Case reports and expert opinion that include narrative literature, reviews and consensus statements</td>
</tr>
</tbody>
</table>

### GRADES OF RECOMMENDATION

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade A</td>
<td>Consistent level I studies</td>
</tr>
<tr>
<td>Grade B</td>
<td>Consistent level II or III studies or extrapolations from Level I studies</td>
</tr>
<tr>
<td>Grade C</td>
<td>Level IV studies or extrapolations from level II or III studies</td>
</tr>
<tr>
<td>Grade D</td>
<td>Level V evidence or troublingly inconsistent or inconclusive studies at any level</td>
</tr>
</tbody>
</table>
approaches to implementing the recommendations and suggested audit criteria that can help with assessing organizational compliance with each recommendation (Table E1).

**Peer review**
A draft of these guidelines were externally peer-reviewed by experts from a range of organizations, countries and professional backgrounds. Additionally the draft guidelines were available on the EAACI website for a three-week period in June 2013 to allow all stakeholders to comment. All feedback was considered by the Prevention Task Force and, where appropriate, final revisions were made according to the feedback received.

**Identification of evidence gaps**
The process of developing these guidelines has identified a number of evidence gaps (Box 5) and we plan in the future to prioritize the questions that the Prevention Task Force believes should be most urgently addressed.

**Editorial independence and managing conflict of interests**
The production of these guidelines were funded and supported by EAACI. The funders did not have any influence on the guideline production process, its contents or on the decision to publish. Conflicts of interest statements were completed by all members of the Task Force and these were taken into account by Task Force chair as recommendations were formulated.

**Updating the guidelines**
We plan to update these guidelines in 2017 unless there are important advances before then.

**Challenges in interpreting the evidence**
Food allergy is a complex topic because the symptoms are diverse and allergies can manifest in many different forms. In children only around one third of parentally reported food allergy can be confirmed

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**Box 4 Recommendations for primary prevention of food allergy**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusive breastfeeding is recommended for all infants for the first 4-6 months</td>
<td>II - III</td>
<td>C</td>
<td>1, 30, 33, 36, 37, 60</td>
</tr>
<tr>
<td>Dietary restrictions are not recommended for all pregnant or lactating mothers</td>
<td>I - II</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>If breastfeeding is insufficient or not possible:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• High-risk infants should receive a hypoallergenic formula with documented preventive effect for the first 4 months. Other infants may receive a standard formula.</td>
<td>I</td>
<td>A-B</td>
<td>1, 47-50, 60</td>
</tr>
<tr>
<td>• After the age of 4 months a standard cow’s milk based formula is recommended according to standard nutrition recommendations, irrespective of atopic heredity</td>
<td></td>
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<td>Introduction of complementary foods after the age of 4 months according to normal standard weaning practices and nutrition recommendations, for all children irrespective of atopic heredity</td>
<td>II – III</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td>No special dietary restrictions after the age of 4 months for infants with high risk for development of allergic disease</td>
<td>II – III</td>
<td>C</td>
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<tr>
<td>No withholding or encouraging exposure to “highly allergenic” foods such as cow’s milk, hens egg and peanuts irrespective of atopic heredity, once weaning has commenced</td>
<td>II – III</td>
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</table>
when appropriately investigated. In the population IgE sensitization to foods, as detected by skin prick test (SPT) or presence of specific IgE (sIgE), is not always associated with clinical reactions and food allergy (6-10). Because the diagnostic accuracy is suboptimal when based solely on history and/or sensitization, if possible a food allergy diagnosis needs to be confirmed by controlled elimination and challenge procedures. Unfortunately, most studies on the prevention of food allergy rely on reported reactions or surrogate markers of food allergy such as sensitization to foods (IgE and/or SPT) and disease outcomes e.g. eczema. Moreover, it is important to be aware of the natural course of food allergy, since food allergies develop in the order of exposure to different foods and many children with food allergies, e.g. cow’s milk allergy, develop tolerance during the first years of life. It is therefore, important to investigate specific food allergies in the relevant age groups when they experience symptoms suggestive of food allergy, and to investigate the specific food allergens that are relevant to that age group and geographic location. Finally, most studies are not sufficiently powered to detect clinically important reductions in the incidence of food allergy.

There are additional ethical and logistical challenges to be considered when interpreting or undertaking food allergy research in young children and infants. For example, it is not ethical to randomize mothers to breastfeeding and evidence on this topic has therefore been based on high-quality observational studies. However, exclusively breastfed children may not be comparable to others due to self-selection and these mothers may be more motivated to exclusively breastfeed due to family history of allergic problems or early symptoms in their children. Thus, there is a risk of reverse causation, which is not taken into consideration in most studies.

It is important to note that the quality assessment in the systematic review was, in keeping with standard practice, undertaken on methodological grounds, rather than on the clinical relevance or overall validity of the studies. When extracting the relevant evidence for the guidelines it is also important to evaluate the scientific quality and clinical relevance of the studies. Thus, for these recommendations on primary prevention of food allergy the above mentioned factors have been considered alongside the formal methodological quality assessment, and experimental studies reporting on confirmed food allergy are ranked highest, whereas studies with self-reported food allergy, atopic symptoms (which may represent food allergy) and sensitization as outcomes are included, but were ascribed less weight. Studies reporting only retrospective data were not included due to their high risk of bias.
PRIMARY PREVENTION

Almost all of the studies focused on dietary strategies of some type. The studies can be conceptually divided into those, which target pregnant women (dietary restrictions and supplements), those which target mothers while breastfeeding (dietary restrictions and supplements) and those, which directly target infants (breastfeeding and exclusive breastfeeding, cow’s milk formula substitutes, supplements, delaying the introduction of complementary foods and dietary restrictions). Other preventive initiatives included vaccinations and multifaceted strategies combining dietary and environmental changes or targeting both mothers and infants simultaneously.

Almost all of the studies focused on preventing the development of food allergy from an early age, i.e. antenatal and infancy and many studies focused on infants at high-risk of allergic disease.

ANTENATAL PREVENTION

Overall, there is no evidence to recommend that women modify their diet during pregnancy or take any supplements such as probiotics in order to prevent food allergy in their children (B).

High-risk families

Currently the evidence supporting the role of specific dietary modifications during pregnancy to prevent food allergy in high-risk children is lacking.

A systematic review (11) and two randomized controlled trials (12, 13) found no benefit from restricting common food allergens among pregnant women.

Fish oil supplements may deserve further investigation as two randomized controlled trials suggested trends towards reduced sensitization to egg (14-16).

One trial found that probiotic supplementation during pregnancy among high-risk families reduced allergic sensitization, but there was no evidence specific to food sensitization or food allergy (17).

Unselected families

In an unselected population (Box 1), one cohort study indicated that maternal intake of foods rich in n-6 polyunsaturated fatty acids and allergenic foods during late pregnancy may increase the risk of childhood sensitization, as opposed to foods rich in n-3 polyunsaturated fatty acids. Also high intake of celery and citrus fruits was associated with an increase in food sensitization, but there were no data on food allergy (18).

PREVENTION STRATEGIES FOR BREASTFEEDING MOTHERS

There is no evidence to recommend that breastfeeding women should modify their diet or take any supplements such as probiotics in order to prevent food allergy in their children (B).

High-risk families

There is no evidence to support intervention strategies for breastfeeding mothers. Two low quality non-randomized comparisons found that maternal dietary changes, i.e. avoidance of the allergenic foods while breastfeeding may not prevent food allergies (19, 20).

One randomized trial found no effect on food sensitization from probiotic supplement during late pregnancy and lactation (21, 22).

Unselected families

One systematic review (23) and two randomized controlled trials (24, 25) found no differences in most allergy outcomes from fish oil supplements taken by unselected populations of breastfeeding women.

PREVENTION STRATEGIES DURING INFANCY

Breastfeeding

Breast-feeding has many benefits for mother and child and is therefore recommended for all infants. There is a small amount of evidence to support breastfeeding as a means of preventing the development of food allergy (C).

The immunomodulatory components, e.g. long chain fatty acid content and oligosaccharides in breast milk may differ from one mother to another, making it complex to study the effect of breast milk per se on allergy prevention (26-28).

High-risk families

Although breastfeeding is widely promoted and has many other benefits, there is limited evidence to draw firm conclusions about the benefit for prevention of food allergies in infants at high-risk. One systematic
review (29) found that most studies identified some benefit of breastfeeding on the risk for food allergy and eczema. One randomized trial of preterm infants indicated a lower risk for cow’s milk protein allergy in high-risk infants fed human bank milk as compared to preterm or term formula (30). However, a cohort study found that those who were exclusively breastfed for 5 months or more were more likely to be sensitized to eggs at one year, but not at two years; no data on food allergy was included (31). Another study found that breastfeeding for 6 months or longer and introducing solid foods after three months was associated with an increased risk for atopy including food sensitization at five years (32). However, the latter study was a part of a trial including other interventions, which makes it difficult to evaluate the effect of breastfeeding.

Unselected families
The evidence is also mixed in unselected populations. One systematic review (29) and four cohort studies (33-36) found that breastfeeding was associated with a reduced risk of food allergy or sensitization in childhood, three found no association in unselected populations (37-39) but one was not powered for food allergy prevention (37), and another was not targeted at food allergy (39). Furthermore, one cohort study suggested an increased risk for self-reported food allergy in those with high-risk only (40).

Infant formulas as alternatives to breastfeeding
There is evidence to recommend that hypoallergenic hydrolyzed cow’s milk based formulas with proven clinical preventive efficacy, are used for infants at high risk, for the first four months, if breastfeeding is insufficient or not possible (B).

High-risk families
There is significant evidence regarding the benefits of hydrolyzed cow’s milk formulas for infants. Two systematic reviews (29, 41) and five randomized trials (42-49) suggested that extensively hydrolyzed whey or casein formulas might have a protective effect. Although one of those (i.e. the GINI study) was not designed for evaluation of food allergy, it reported on atopic eczema/dermatitis and allergic manifestations including gastrointestinal food allergy (food allergy with manifestations in the gastrointestinal tract), and food sensitization (45, 46). Two other randomized comparisons failed to find a benefit (50, 51). However, in one of these, the children were breastfed for a long period and the formula was introduced after the age of six months (50), which may indicate that the window of opportunity for prevention with hydrolyzed formulas are likely to be restricted to the first six months. Another randomized trial combining extensively hydrolyzed casein based formula with avoidance of some foods for varying periods and maternal diet, also found a benefit of extensively hydrolyzed casein based formula on food allergy until three years of life (47-49), but is difficult to contribute the effect seen to the hydrolyzed formula only. In one of the systematic reviews food allergy were not reported separately, only as part of atopic symptoms (41). The Swedish study (50) reported on symptoms suggestive of food allergy, whereas the others reported on confirmed food allergy. Partially hydrolyzed infant formula may also have a protective effect. Two systematic reviews (52, 53), two randomized controlled trials (45, 54) and two non-randomized comparisons (55, 56) found that partially hydrolyzed formula may protect against food allergy, and the latter two found that ‘food allergy symptoms’ or ‘sensitization’ may be reduced when compared to standard cow’s milk formula. As described above, the GINI study (45) reported on eczema and allergic manifestations, including gastrointestinal food allergy, rather than food allergy (45, 46). One randomized trial (57) and one non-randomized comparison (58) failed to find any benefit. However, in one (57) outcomes were only assessed by telephone interview.

A few studies have compared the possible preventive effects of extensively and partially hydrolyzed formulas. They indicate that the preventive efficacy is dependent on the specific formula studied. The degree of hydrolysis alone may not correlate with the efficacy of prevention of food allergy (59), and also different extensively hydrolyzed formulas may have different effects. Thus, an extensively hydrolyzed whey formula used in the GINI study (45) was not effective for prevention, whereas another extensively hydrolyzed whey formula was effective in other studies (42, 43) and extensively hydrolyzed casein formula has been effective in several studies (42, 43, 47, 48, 60). A few studies indicated that some extensively hydrolyzed formulas (based on casein or whey) might have a better preventive effect as compared to partially hydrolyzed whey formula (42) or a blend of casein and whey (44), although a meta-analysis found no significant difference (53).
There was no evidence to support the use of soy-based formulas in allergy prevention. One systematic review (61) and two randomized trials (57, 62) found that soy-based formulas might not protect against food allergies when compared to cow’s milk formula or to other alternatives. However, in one of the latter (57) outcome were assessed by telephone interview.

Unselected families
There were no available data, as these studies have not been performed.

Dietary supplements
There is no evidence to recommend pre- or probiotics or other dietary supplements based on particular nutrients to prevent food allergy (B).

Pre- and probiotic supplements

High-risk families
Probiotic supplements have been tested during infancy, but there is little evidence to support their effectiveness. Four randomized controlled trials (63-66) found no benefit against food allergy or sensitization.

Unselected families
There is no evidence to support prebiotics or probiotics to prevent food allergy in unselected or mixed-risk populations. One systematic review (67) found insufficient evidence about the benefits of prebiotics in infant formulas and one randomized trial using a particular blend of neutral oligosaccharides and pectin-derived acidic oligosaccharides (68) found benefit for eczema but not for food sensitization. Two systematic reviews (69, 70) and one randomized trial (71) found no benefit of using probiotics in unselected or mixed populations.

However, different microorganisms have been used in different studies, and it appears that different microbial strains may have different effects, which may explain the inconsistent results as regards a possible preventive effect of specific strains of probiotics.

Other supplements
One randomized trial (72) found no evidence to recommend or avoid cow’s milk-based human milk fortifiers in premature infants, though the study may not be powered for food allergy as an outcome. One cohort study (73) found no evidence to recommend or avoid vitamins A and D as water-soluble or in peanut oil.

Introduction of complementary foods

There is insufficient evidence to make specific recommendations about the timing of the introduction of complementary foods and individual solid foods in regards of food allergy prevention for all children (C). However, a few studies indicate that it might be an advantage not to introduce solids before four months of age (C). In addition, other aspects have to be considered, such as the infant’s developmental readiness, parental opinion/needs, the nutritional needs and the risk for developing very selective eating habits. Therefore, we recommend introducing complementary foods from 4-6 months of age according to standard local practices and the needs of the infant, irrespective of atopic heredity.

High-risk families
Another strategy has been to delay the introduction of solid foods. Infants may not need or may not be developmentally ready to start eating solid foods until sometime within the age range of 4-6 months, so this period is often considered as an appropriate minimum weaning age. Some studies suggest that introducing solid foods earlier than four months may increase the risk of food sensitization and eczema in infants with a family history of allergy. However, delaying the introduction of solid foods beyond four months does not seem to confer any additional protective benefits. Two low quality cohort studies (74, 75) found no evidence that introducing solid foods after four months in high-risk infants prevented food allergy. This finding is supported by the low prevalence of food allergy in randomized trials on hydrolyzed formulas without delaying introduction of solid foods after 4 - 6 months (42, 43).

Unselected families
One systematic review (76) and two cohort studies (77, 78) found that introducing solid foods after four months did not protect against food allergy; but one of these (77) found that introduction of solid foods before four months increased the risk of later allergy. Two cohort studies found reduced food sensitization
when solids were introduced earlier than four months (37, 79), in the latter only in those at high-risk.

**Introduction of potential food allergens**

The timing of potential food allergen introduction may be important, but there is insufficient rigorous scientific evidence in this regard; the present evidence does not justify recommendations about either withholding or encouraging exposure to potentially allergenic foods during infancy (B-C). Therefore, for primary prevention we recommend no withholding or encouraging of exposure to “highly allergenic” foods such as cow’s milk, hen’s egg and peanuts irrespective of atopic heredity, once weaning has commenced.

Two randomized controlled trials (80-82) found that there was no increased risk of food allergy from early exposure to cow’s milk protein in the first three days of life, but in one (80, 81) the diagnostic criteria for food allergy were weak and not documented by challenges, while for the other one (82) the symptoms were nonspecific and food allergy was not reported. Another randomized trial (83) and one cohort study (36) suggested an increased risk of confirmed cow’s milk allergy if children in unselected populations were fed cow’s milk protein in the first few days.

There is little additional evidence about avoiding potential food allergens. One cohort study found (84) that consuming fish regularly during the first year of life may protect against food allergy or sensitization.

In a large cross-sectional study, not included in the systematic review because of its design, comparing Israeli and UK Jewish children, the prevalence of peanut allergy was 10-fold higher in the UK than in Israel whereas the median monthly consumption of peanuts in Israeli infants was very high but merely absent in the UK (85). This observation reports an interesting association, which awaits confirmation in further studies (86). Another cross-sectional study with retrospective data on introduction indicated that introduction of egg between 4-6 months might protect against egg allergy (87), but due to the methods, these data needs to be confirmed in other studies.

One recent nested control study, including children from a prospective birth-cohort study, found that children diagnosed with food allergy by two years were introduced solids earlier (≤ 16 weeks) and were less likely to be receiving breast milk when cow’s milk protein was first introduced into their diet (88). Thus, introducing potential food allergens while continuing to breastfed may provide a reduced risk for development of food allergy. However, studies using rigorous design methodologies are required to answer this important question with greater certainty.

**Combining dietary with environmental modifications**

Although the quality of evidence is low, there is some evidence from six studies (89-95) to suggest that combining dietary with different environmental recommendations or modifications, such as reduction of exposure to house dust mite allergens, during infancy for high-risk families may be useful (B). Further research in this area would be helpful because there are few data about specific food allergy outcomes and it is difficult to differentiate cause and effect relationships in the available literature.

**Prevention strategies during childhood and adulthood**

Very little has been published about strategies to prevent food allergy targeting children and adults, and all available studies are in unselected populations. One systematic review (96) found that Bacillus Calmette–Guérin (BCG) vaccinations had no protective effect against food allergy and another systematic review (97) found no protective benefit from fish oil supplements. A cohort study (98) found that taking vitamins before age five may protect against food allergy, but the quality of evidence is very low (C).

**Conclusions and future perspectives**

Based on this evidence families can be provided with some practical advice about preventing food allergy, particularly amongst infants at high-risk due to parent and/or older siblings with allergic disease (Box 6). The advice for all mothers includes the consumption of a normal healthy diet without restrictions during pregnancy and lactation. For all infants exclusive breastfeeding is recommended for the first 4-6 months of life. If breastfeeding is insufficient or not possible for the first four months, infants at high-risk can be recommended a hypoallergenic formula.
Recommendations for all infants:
• No special diet during pregnancy or for the lactating mother
• Exclusively breastfeeding for 4 – 6 months

Further recommendations for high-risk infants:
• If supplement is needed during the first 4 months a documented hypoallergenic formula is recommended

Introduction of complementary foods after the age of 4 months according to normal standard weaning practices and nutrition recommendations, for all children irrespective of atopic heredity

with documented preventive effect for the first 4 months of life. There is no need to avoid introducing complementary foods beyond four months or for infants and children to take supplements such as prebiotics or probiotics. In addition, the present evidence does not justify recommendations about either withholding or encouraging exposure to potentially allergenic foods after the age of four months, once weaning has commenced, irrespective of atopic heredity.

Although no cost-effect or cost-benefit analysis has been published, the above recommendations are easy to follow, at low cost and are not detrimental (D). It may be necessary to consider the levels of evidence, as well as the price and the possibility for reimbursement of extra expenses for the different hydrolyzed formulas. Whilst considering these recommendations, it should be remembered that a lack of evidence for some issues, does not necessarily mean they are not useful, merely that there is yet insufficient proof of a potential benefit. In this regard, there is a need for future studies.

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Authors’ contribution

Antonella Muraro, Chair of the EAACI Food Allergy and Anaphylaxis Guidelines Initiative, has steered and coordinated the publication. Susanne Halken chaired the guidelines group with support from Arne Høst. Debra de Silva and Sukhmeet Panesar undertook the supporting systematic reviews under the supervision of Aziz Sheikh. All authors participated in the discussion of the systematic review, the evidence table, recommendations, gaps and specific sections and approved the final version.

Conflicts of interest

Susanne Halken has provided scientific advice for ALK-Abello. Antonella Muraro has provided scientific advice for Meda. Tony DuBois has provided scientific advice for ALK-Abello and received funding from ALK Abello to support his research activities. Philippe Eigenmann has provided scientific advice for Danone, Novartis, ALK, DBV technologies and Stallergenes; he has received funding for research activities from LETI, Nestlé and ThermoFisher. Arne Høst has provided scientific advice for ALK-Abello and Danone. Carina Venter has produced educational material for Danone, Med Johnson and Nestlé and has received research funding from Thermosticher, Danone and Med Johnson. Debra de Silva, Sukhmeet Panesar and Aziz Sheikh have received funding for coordinating guideline production, and generating the systematic reviews from EAACI. Aziz Sheikh has provided scientific advice to ALK-Abello, Meda, Lincoln Medical, ThermoFisher, Pfizer and Stallergenes; he is on the Anaphylaxis Campaign UK’s Scientific Committee, World Allergy Organization’s Anaphylaxis Special Committee, UK Resuscitation Council’s Anaphylaxis Committee and the BSACI’s Standard of Care Committee. Gideon Lack has no conflict of interests. Kirsten Beyer has received funding for research activities from the European Union, German Research Foundation, Berliner Sparkasse, BEA-Stiftung, Food Allergy and Anaphylaxis Network, Food Allergy Initiative, Danone, ThermoFisher, DST Diagnostics, Allergopharma and has received honoraria or consultation fee from Danone, MedaPharma, ALK-Abelló, Novartis, Unilever, Allergopharma, MedUpDate, ThermoFisher, HAL. Graham Roberts
and Hasan Arshad have provided scientific advice for Danone. Kate Grimshaw has provided scientific advice for Danone. Valérie Verhasselt has received research funding from GSK. George du Toit has received lecture fees from Nutricia and indirectly from the many sponsors of the KCL Allergy Academy. Cesmi A Akdis has received research grants from Allergopharma, Stallergenes, Actellion and Novartis. Besides, Cesmi A Akdis was President (2011-2013), Past President (2013-2015) and ExCom member in EAACI that has received financial support from several relevant business entities.

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### Appendix

#### Barriers and facilitators to implementation, audit criteria and resource implications of recommendations

<table>
<thead>
<tr>
<th>Exclusive breastfeeding is recommended for all infants for the first 4-6 months</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of support at the nursery, from family and friends</td>
<td>Breastfeeding is a general recommendation for nutrition of infants and young children</td>
<td>Human milk provides the nutritional needs for normal children until the age of 4-6 months</td>
</tr>
<tr>
<td>Lack of maternity leave</td>
<td>Very few contraindications to breastfeeding</td>
<td>It is easy and cheap</td>
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<table>
<thead>
<tr>
<th>Evidence level</th>
<th>Grade</th>
<th>Key references</th>
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<tbody>
<tr>
<td>II-III</td>
<td>C</td>
<td>1, 30, 33, 36, 37, 60</td>
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</table>

| Audit criteria | ≥ 75 % of all infants are breastfed for ≥ the first 4 months |

<table>
<thead>
<tr>
<th>No dietary restrictions for all pregnant or the lactating mother for allergy preventive purposes</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
</tr>
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<tr>
<td>Should be none</td>
<td>It is not an intervention, but normal unrestricted diet for women</td>
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<tr>
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<th>Grade</th>
<th>Key references</th>
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<tr>
<td>I-III</td>
<td>B</td>
<td>1</td>
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</table>

| Audit criteria | All pregnant and lactating women should have no dietary restriction to prevent allergy in their children |

<table>
<thead>
<tr>
<th>If breastfeeding is insufficient or not possible: • High-risk infants should receive a hypoallergenic formula with documented preventive effect for the first 4 months. Other infants may receive a standard formula. • After the age of 4 months a standard cow’s milk based formula is recommended according to standard nutrition recommendations, irrespective of atopic heredity</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited access to documented hypoallergenic formulas with documented preventive effect</td>
<td>It is a very little restrictive intervention</td>
<td></td>
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<tr>
<td>Costs for hypoallergenic formulas with documented preventive effect</td>
<td>Limited need for hypoallergenic formula in breastfed children</td>
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<td>A-B</td>
<td>1, 47-50, 60</td>
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<table>
<thead>
<tr>
<th>Audit criteria</th>
<th>≥ 75 % high risk infants are breastfed for ≥ 4 months</th>
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<tbody>
<tr>
<td>≥ 75 % high risk infants have documented hypoallergenic formula if needed in the first 4 months</td>
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<tr>
<td>≥ 75 % high risk infants ≥ 4 month are offered normal and adequate nutrition without restrictions for preventive purposes</td>
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| Audit criteria | ≥ 75 % of all infants are breastfed for ≥ the first 4 months |

<table>
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<th>Facilitators to implementation</th>
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<tbody>
<tr>
<td>Little, if any</td>
<td>This is normal nutritional practice adequate for the particular age</td>
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<tr>
<td>Misleading advice</td>
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| Audit criteria | ≥ 90% of all infants and children avoid unnecessary dietary restrictions |
SECTION 3

QUALITY OF LIFE IN FOOD ALLERGY
3.1

DISEASE-SPECIFIC HEALTH-RELATED QUALITY OF LIFE INSTRUMENTS FOR IgE-MEDIATED FOOD ALLERGY

SYSTEMATIC REVIEW

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On behalf of the EAACI Food Allergy and Anaphylaxis Group: C Bindslev-Jensen, V Cardona, P Eigenmann, N Papadopoulos, B Vlieg-Boerstra, CA Akdis
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**Background:** This is one of seven inter-linked systematic reviews undertaken on behalf of the European Academy of Allergy and Clinical Immunology as part of their Guidelines for Food Allergy and Anaphylaxis, which focuses on instruments developed for IgE-mediated food allergy. Disease-specific questionnaires are significantly more sensitive than generic ones in measuring the response to interventions or future treatments, as well as estimating the general burden of food allergy. The aim of this systematic review was therefore to identify which disease-specific, validated instruments can be employed to enable assessment of the impact of, and investigations and interventions for, IgE-mediated food allergy on health-related quality of life.

**Methods:** Using a sensitive search strategy, we searched seven electronic bibliographic databases to identify disease-specific quality of life tools relating to IgE-mediated food allergy.

**Results:** From the 17 eligible studies, we identified seven disease-specific health-related quality of life instruments, which were then subjected to detailed quality appraisal. This revealed that these instruments have undergone formal development and validation processes, and have robust psychometric properties, and therefore provide a robust means of establishing the impact of food allergy on quality of life.

**Conclusions:** Suitable instruments are now available for use in children, adolescents, parents/caregivers, and adults. Further work must continue to develop a clinical minimal important difference for food allergy, and for making these instruments available in a wider range of European languages.

BACKGROUND

The term ‘food allergy’ refers to the sub-group of food-triggered reactions in which immunologic mechanisms have been implicated, whether IgE (Immunoglobulin E)-mediated, non-IgE-mediated, or involving a combination of IgE- and non-IgE-mediated etiologies (1). This review focuses on food allergy that is likely to have an IgE-mediated etiology.

Living with a food allergy is more difficult than is generally appreciated (2). Long-term management is focused on the avoidance of the food(s) that trigger the allergic reactions, which in turn places a psychological burden on patients and carers that can result in stress and anxiety. There is, in addition, often further anxiety relating to the burden of managing acute reactions – particularly if the decision to administer adrenaline (epinephrine) also falls on the patient and/or carer (3–6). In some cases, this can have a considerable impact on the day-to-day lives of patients and carers (7).

The importance of measuring health-related quality of life (HRQL) in patients is that such measurement allows for the estimation of the impact of the disease from a patient perspective; this is important because it is possible for two individuals with clinically similar disease severity to experience very different degrees of impairment in their everyday lives (8).

HRQL can be measured using generic or disease-specific questionnaires. Useful attributes of generic quality of life (QOL) questionnaires are that they allow comparison between different diseases as well as being sensitive to co-morbidities. However, associated limitations of generic instruments include the fact that they are less sensitive and responsive to change than disease-specific instruments, hence potentially important differences or changes may be missed. This is particularly relevant in the context of food allergy, where, unless individuals are exposed to the specific food, they may have no symptoms or problems other than the anxiety resulting from the need for continued avoidance (9). The disease-specific questionnaires that have been developed are significantly more sensitive in measuring the response to interventions or future treatments as well as estimating the general burden of food allergy (10).

This systematic review is one of seven inter-linked evidence syntheses that has been undertaken in order to provide a state-of-the-art synopsis of the current evidence base in relation to epidemiology, prevention, diagnosis and clinical management and impact on QOL. This will be used to inform clinical recommendations in the EAACI Guidelines for Food Allergy and Anaphylaxis. This review will consider only instruments developed for IgE-mediated food allergy.

AIMS

We sought to identify which disease-specific, validated instruments can be employed to enable assessment of the impact of, and the effect of investigations and interventions for, food allergy on HRQL.

METHODS

Registration and protocol

This review is registered with the International Prospective Register of Systematic Reviews (PROSPERO; http://www.crd.york.ac.uk/PROSPERO/) and has the reference number CRD42013003710. Detailed information on our methods, including the search strategy, study selection, quality assessment strategy, analysis, data synthesis and reporting have been reported in advance in our published protocol (11). We provide a brief synopsis of our methods below.

Search strategy

A sensitive search strategy was designed to retrieve all articles combining the concepts of food allergy, QOL and patient-reported outcomes from electronic bibliographic databases. The search strategy was devised on OVID MEDLINE and then adapted for the other databases (see Data E1 for full search strategies). In all cases, the databases were searched from January 1, 1990 to September 30, 2012. Our rationale for searching from 1990 onwards was that this marked the first publication of key allergy HRQL instruments such as the Rhinoconjunctivitis Quality of Life Questionnaire (RQLQ) and Asthma Quality of Life Questionnaire (AQLQ) (12, 13).

Inclusion and exclusion criteria

We specified that the disease-specific HRQL questionnaire must have been specifically designed for use with patients and carers with food allergy. Any articles relating to the description, development and/or the validation of the above identified HRQLs were also eligible for inclusion. Excluded studies included
reviews, discussion papers, non-research letters, editorials, case studies and case series.

**Study selection**
The titles were checked independently by two reviewers (SAS and SSP) according to the selection criteria and categorized as: included, not included and unsure. For those papers in the unsure category, we retrieved the abstract and re-categorized. Any discrepancies were resolved by consensus and, if necessary, a third reviewer (AS) was consulted to arbitrate. Full text copies of potentially relevant studies were obtained and their eligibility for inclusion independently assessed.

**Quality assessment strategy**
We assessed the development of the instruments identified and their performance properties including: validity; generalizability; responsiveness; managing missing data; how variation in patient demography was managed; and cross-cultural and linguistic adaptation, using a previously reported quality assessment tool (14). Assessment of validity focused on identification of appropriate independent measures and their correlation with partial or total instrument scores. A team of researchers (SAS and SSP) independently assessed the articles against the defined criteria and any discrepancies were resolved by consensus and, if necessary, a third reviewer (AS) was consulted.

**Analysis, data synthesis and reporting**
Data were independently extracted onto a customized data extraction sheet by two reviewers (SAS and SSP), and any discrepancies were resolved by discussion or, if agreement could not be reached, by arbitration by a third reviewer (AS). A descriptive summary with data tables was produced to summarise the literature. Quantitative pooling of data was not meaningful in the context of this review so a narrative synthesis of the data was undertaken.

**RESULTS**

**Study selection**
The electronic database searches identified 1255 papers of potential interest. Seventeen studies met the inclusion criteria. The most frequent reason for exclusion was that the questionnaire was not a disease-specific HRQL instrument, was not validated or was inadequately validated (Figure 1).

From the 17 studies, seven disease-specific HRQL instruments were identified for food allergy as requiring full quality appraisal. Further details are found in Table 1. Four subtypes were identified: those to be completed by adults, adolescents, older children, and parent or caregiver. The characteristics of each of the HRQLs are presented in Table 2, a summary of their development is detailed in Table 3 and the psychometric properties of these instruments are summarised in Table 4.

**Food allergy disease-specific HRQL for children**

*Food Allergy Quality of Life Questionnaire Child Form (FAQLQ-CF)*
The food allergy QOL questionnaire child form (FAQLQ-CF) was developed as the first disease-specific HRQL questionnaire for food allergic children that can be self-administered, originally in the Dutch language. Four papers were reviewed for the development and validation of the FAQLQ-CF in this review (9, 10, 15-16).

The intended population was for children aged 8 to 12 years and is a self-report; it contains 24 items and four domains. This instrument was developed as part of the EuroPrevall project, a European multi-centre research project on food allergy, to cover all age groups of patients with food allergy.

The FAQLQ-CF was developed following item generation and item reduction (12-14, 17). Cross-sectional validity was assessed through evaluation of its construct validity, convergent and discriminant validity, discriminative ability and reliability. Food Allergy Independent Measure (FAIM), a disease-specific objective instrument, was developed for the validation of the FAQLQ and included four expectation of outcome (EO) questions and two independent measure (IM) questions (18, 19). One study demonstrated moderate correlation between FAQLQ-CF and FAIM (rho = 0.60, p = <0.001) (9) and two studies showed similar internal consistency (Cronbach’s α = 0.94 – 0.95) (7, 20). The instrument also demonstrated that it could discriminate between children who differed in number of food allergies (> 2 food allergies versus ≤ 2 food allergies, total FAQLQ-CF score 4.3 versus 3.6, p = 0.036). However, FAQLQ-CF could not discriminate between reported anaphylaxis or not (4.2 versus 3.9, p = 0.315) (9).
Figure 1 PRISMA flow diagram showing the study identification process. The diagram shows the process we followed to identify relevant studies, and the number of studies that were included or excluded at each stage.

Table 1 Disease-specific HRQL instruments

<table>
<thead>
<tr>
<th>Abbreviation (where stated)</th>
<th>Full name</th>
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</thead>
<tbody>
<tr>
<td><strong>CHILDREN</strong></td>
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<tr>
<td>FAQLQ-CF (9, 10, 15, 16)</td>
<td>Food Allergy Quality of Life Questionnaire Child Form</td>
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<tr>
<td><strong>adolescent</strong></td>
<td></td>
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<tr>
<td>FAQLQ-TF (10, 20, 21)</td>
<td>Food Allergy Quality of Life Questionnaire Teenager Form</td>
</tr>
<tr>
<td>FAQL-teen (22)</td>
<td>Food Allergy Quality of Life Assessment Tool For Adolescents</td>
</tr>
<tr>
<td>You and Your Food Allergy (23)</td>
<td>You and Your Food Allergy</td>
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<tr>
<td><strong>adults</strong></td>
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<tr>
<td>FAQLQAF (10, 24, 25)</td>
<td>Food Allergy Quality of Life Questionnaire Adult Form</td>
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<tr>
<td><strong>parent or caregiver</strong></td>
<td></td>
</tr>
<tr>
<td>FAQL-PB (19, 26-29)</td>
<td>Food Allergy Quality of Life Parental Burden</td>
</tr>
<tr>
<td>FAQLQ-PF (7, 15, 29, 30)</td>
<td>Food Allergy Quality of Life Questionnaire Parent Form</td>
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</tbody>
</table>
Table 2 Characteristics of included instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Aim of the study and target population</th>
<th>No. items/domain</th>
<th>Mode of administration</th>
<th>Time to complete</th>
<th>Original language</th>
<th>Language available in</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR CHILDREN</strong></td>
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</tbody>
</table>
| FAQLO-CF (9, 10, 15, 16) | To develop and validate the Food Allergy Quality of Life Questionnaire – Child Form (FAQLO-CF) | 24 items and 4 domains: 
- a- allergen avoidance 
- b- risk of accidental exposure 
- c- emotional impact 
- d- dietary restrictions | Self-administered by children | Not published | Dutch | French, Dutch, English |
| **FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR ADOLESCENT** | | | | | | |
| FAQLO-TF (10, 20, 21) | To develop and validate the Food Allergy Quality of Life Questionnaire – Teenager Form (FAQLO-TF) | 28 items and 3 domains: 
- a- dietary restrictions 
- b- emotional impact 
- c- risk of accidental exposure | Self-administered by adolescents | Not published | Dutch | Dutch, English |
| FAQL-teen (9) | To develop a validated Food Allergy Quality of Life assessment tool for US adolescents (FAQL-teen) | 17 items. Domains not mentioned | Self-administered by adolescents | Not published | English | English |
| **FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR ADULTS** | | | | | | |
| FAQLO-AF (10, 24, 25) | To report the development and cross-sectional validation of the first disease-specific HRQL questionnaire for adults with food allergy. Intended populations: Adults over 18 years old with food allergy excluding those with oral allergy syndrome | 29 items and 4 domains: 
- a- dietary restrictions 
- b- emotional impact 
- c- risk of accidental exposure 
- d- food allergy-related health | Self-administered by adults | Not published | Dutch | Dutch, English |
| **FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR PARENT OR CAREGIVER** | | | | | | |
| FAQLO-PB (18, 26-29) | To create a validated, food allergy-specific HRQL instrument to measure parental burden associated with having a child with food allergy. Intended population: Parents of children ≤17 years old | 17 items and 3 domains: 
- a- going on vacation 
- b- social activities 
- c- worries and anxieties | Self-administered by parents | Not published | English | Chinese, English |
| FAQLO-PF (7, 15, 29, 30) | To develop a sensitive, multi-dimensional measure to assess parental perception of the child’s HRQL. Intended population: Parents of children aged 0–12 years old | 30 items and 3 domains: 
- a- emotional impact 
- b- food-related anxiety 
- c- social and dietary limitations | Self-administered by parents | Not published | Dutch | French, Dutch, English |
### Table 3  Summary of development properties of included HRQL instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Pre-study hypothesis</th>
<th>Intended population</th>
<th>Actual content area (face validity)</th>
<th>Item identification</th>
<th>Item selection</th>
<th>Uni-dimensionality</th>
<th>Response scale</th>
<th>Scoring</th>
<th>Instrument translated and validated in English speaking population</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>FAQLO-CF (9, 10, 15, 16)</td>
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<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
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<tr>
<td>FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR ADOLESCENTS</td>
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<tr>
<td>FAQLO-TF (10, 20, 21)</td>
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<td>✓ ✓</td>
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<tr>
<td>FAQL-teen (22)</td>
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<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓ ✓</td>
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<tr>
<td>You and Your Food Allergy (23)</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓ ✓</td>
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<td>✓ ✓</td>
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<td>✓</td>
<td>✓ ✓</td>
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<tr>
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<tr>
<td>FAQL-PB (19, 26-29)</td>
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<td>✓ ✓</td>
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<td>✓ ✓</td>
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<tr>
<td>FAQLO-PF (7, 15, 29, 30)</td>
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<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓</td>
<td>✓ ✓</td>
<td>✓</td>
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</tbody>
</table>

(For definitions refer to Table E2)
### Table 4  Summary of psychometric properties of included HRQL instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Convergent validity</th>
<th>Discriminant validity</th>
<th>Predictive validity</th>
<th>Other evidence for construct validity e.g. criterion, discriminant</th>
<th>Assessment of validity (cross-sectional, longitudinal or both)</th>
<th>Test-re-test agreement</th>
<th>Inter-observer agreement or inter-mode agreement</th>
<th>Person/ item separation reliability</th>
<th>Interpretation</th>
<th>Responsiveness</th>
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<tbody>
<tr>
<td><strong>FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR CHILDREN</strong></td>
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<tr>
<td>FAQLO-CF (9, 10, 15, 16)</td>
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<td>✓✓</td>
<td>0</td>
<td>FAIM CHQ-CF87</td>
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<td>0</td>
<td>✓</td>
<td>0</td>
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<tr>
<td><strong>FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR ADOLESCENTS</strong></td>
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<tr>
<td>FAQLO-TF (10, 20, 21)</td>
<td>✓✓</td>
<td>✓✓</td>
<td>0</td>
<td>FAIM CHQ-CF87</td>
<td>Cross-sectional</td>
<td>✓✓</td>
<td>✓✓</td>
<td>0</td>
<td>✓</td>
<td>0</td>
</tr>
<tr>
<td>FACL-teen (22)</td>
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<td>0</td>
<td>PedsQL</td>
<td>Cross-sectional</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>✓</td>
<td>0</td>
</tr>
<tr>
<td>You and Your Food Allergy (23)</td>
<td>✓✓</td>
<td>✓✓</td>
<td>0</td>
<td>PedsQL</td>
<td>Cross-sectional</td>
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<td>✓✓</td>
<td>0</td>
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<td>0</td>
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<tr>
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<tr>
<td>FAQLO-AF (10, 24, 25)</td>
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<td>0</td>
<td>FAIM RAND-36</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td><strong>FOOD ALLERGY DISEASE-SPECIFIC HRQL FOR PARENT OR CAREGIVER</strong></td>
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<tr>
<td>FAQLO-PB (19, 26-29)</td>
<td>✓✓</td>
<td>✓✓</td>
<td>0</td>
<td>CHQ-PF50</td>
<td>Cross-sectional</td>
<td>✓✓</td>
<td>✓✓</td>
<td>0</td>
<td>✓</td>
<td>0</td>
</tr>
<tr>
<td>FAQLO-PF (7, 15, 29, 31)</td>
<td>✓✓</td>
<td>✓✓</td>
<td>0</td>
<td>FAIM</td>
<td>Both</td>
<td>✓✓</td>
<td>✓✓</td>
<td>0</td>
<td>✓✓</td>
<td>✓✓</td>
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</table>

(For definitions refer to Table E2)
One of the four studies also evaluated test-retest reliability of the FAQLQ-CF. The intraclass coefficient (ICC) was found to be excellent (ICC = 0.91) \((10)\) and the same study identified the concordance correlation coefficient (CCC) as 0.907, as well as a Bland-Altman plot demonstrating that the mean differences of the test and re-test were close to zero for the FAQLQ-CF \((10)\).

One study validated the French version of instrument. The results demonstrated the converted FAQLQ-CF had good internal consistency (Cronbach’s \(\alpha = 0.67\)) and a good correlation between FAQLQ-CF and FAIM-CF \((r = 0.84)\) \((15)\). One study identified in this review compared child self-reported and parent-proxy-reported HRQL in food allergic children \((8-12\) years old). The study assessed the FAQLQ-CF and FAQLQ Parental Form (PF) in Dutch food-allergic child-parent pairs. Child and parent proxy reports were correlated and tested for significant differences, including the comparison of the internal consistency and construct validity. The results demonstrated the correlation coefficient between the total FAQLQ-CF and FAQLQ-PF to be 0.56 \((p = <0.001)\). The ICC was 0.57 \((p = <0.001)\). The Bland-Altman plot showed that the mean between the FAQLQ-CF and FAQLQ-PF score was 1.06 \((SD = 1.10)\) \((15)\).

### Food allergy disease-specific HRQL for adolescents

**Food Allergy Quality of Life Questionnaire Teenager Form (FAQLQ-TF)**

This tool was developed as the first disease-specific HRQL questionnaire for food allergic adolescents, originally in the Dutch language. Three papers were reviewed for the development and validation of the FAQLQ-TF \((10, 20, 21)\).

The intended population included patients aged 13 to 17 and is a self-report; it contains 28 items and three domains.

This instrument was developed as part of the EuroPrevall project and followed the development and validation method of the FAQLQ-CF. Assessment demonstrated correlation between FAQLQ-TF and FAIM \((p = 0.57, p = <0.001)\) with an internal consistency (Cronbach’s \(\alpha = 0.92)\). Additionally, the instrument demonstrated that it could discriminate between adolescents who reported two or more food allergies compared to adolescents who only reported one \((1\) food allergies versus \(>2\) food allergies, total FAQLQ-TF score 4.3 versus 3.5, \(p = 0.037)\). However, FAQLQ-TF could not discriminate between those who did or did not have reported anaphylaxis \((4.5\) versus \(4.0, p = 0.184)\) \((20)\).

One of the three studies also evaluated the test-retest reliability of the FAQLQ-TF, which was excellent \((ICC = 0.976 and CCC = 0.975)\). The Bland-Altman plot also illustrated that the mean differences of the test and re-test was close to zero for the FAQLQ-TF \((10)\). Another study identified in this review went on to further compare adolescent self-reported and parent-proxy-reported HRQL of food allergic adolescents and to investigate the factors that may influence any disagreements between the two; this was an area which had not been previously studied \((21)\). This third study assessed the Teenager Form (TF) and Parental Form (PF) of the FAQLQ but also FAIM and brief-illness perception questionnaire (Brief-IPQ). The results comparing FAQLQ-TF and FAQLQ-PF showed that there was moderate correlation \((ICC = 0.61, p = <0.001)\) and no significant difference \((3.78\) versus \(3.56, p = 0.103)\) between adolescent-self reported and parent-proxy-reported HRQL at group level. The Bland-Altman plot showed relevant differences (exceeding the minimal important difference) for 63% of the adolescent-parent pairs \((21)\).
You and Your Food Allergy

One study was identified which reviewed the development and validation of a disease-specific HRQL scale of teenagers aged 13 to 18 years with food hypersensitivity living in the UK (17). It is a self-report and contains 34 items and five domains.

The HRQL scale was developed in four stages: stage one was the development of a preliminary HRQL scale and stage two involved pre-testing the preliminary scale. Stage three was the testing of the pilot scale to identify problematic items and stage four reduced the number of items in the field test scale to those best measuring HRQL.

The whole scale involved internal consistency (Cronbach’s α = 0.92) and the test-re-test reliability (ICC = 0.87) (23). The scale correlated with a generic HRQL scale (PedsQL) and discriminated by disease severity. For the known-groups analysis, there was significant difference between the whole scale scores of those allergic to ≤ 2 foods [mean (s.d) = 71.7(13.1)] and those allergic to >2 foods [mean (s.d) = 67.5 (14.1)]. This supports the scales ability to distinguish between groups hypothesized to have differing HRQL (t = 2.459, df = 287, p <0.05) (23).

Food allergy disease-specific HRQL for adults

Food Allergy Quality of Life Adult Form (FAQLQ-AF)

The food allergy QOL adult form was developed, in Dutch, as the first disease-specific HRQL questionnaire for adults. Three papers were reviewed for the development and validation of the FAQLQ-AF in this systematic review (10, 24, 25). The intended population for the questionnaire was patients over the age of 18 years and is a self-report; it contains 29 items and four domains.

This instrument was developed as part of the EuroPrevall project and followed the development and validation method of the FAQLQ-CF and -TF. This instrument was the last of the HRQL questionnaires, in a series of questionnaires developed in the EuroPrevall project. The FAQLQ-AF was developed following item generation and item reduction (12-14, 17). Cross-sectional validity was assessed through evaluation of its construct validity, convergent and discriminant validity, discriminative ability and reliability. Assessment of this tool demonstrated good correlation between FAQLQ-AF and FAIM (ρ = 0.76, p =<0.001) with internal consistency (Cronbach’s α = 0.97) (25). Additionally, the instrument demonstrated that it could discriminate between patients who differ in severity of symptoms (anaphylaxis versus non-anaphylaxis, total FAQLQ-AF score 4.9 versus 4.1 p = 0.041) and number of food allergies (>3 food allergies versus ≤ 3 food allergies, total FAQLQ-AF score 5.2 versus 4.2, p = 0.008) (25). In addition, one of the studies evaluated the test-re-test reliability of the FAQLQ-AF which was excellent (ICC = 0.952 and CCC = 0.952).

In 2010, the FAQLQ-AF was translated from Dutch to English for an online version to be used in the US. One study identified in this review validated this translated instrument. The online FAQLQ-AF also demonstrated a good construct validity (correlation with FAIM ρ = 0.72; p = <0.001), internal consistency (Cronbach’s α = 0.95) and was discriminative for anaphylaxis versus non-anaphylaxis (total FAQLQ-A score 5.4 versus 4.9 p = 0.03). Discriminative ability was also shown in American participants allergic to more than three foods versus participants allergic to three or fewer foods (5.7 versus 5.1; p = <0.001) (24).

Food allergy disease-specific HRQL for parent or caregiver

Food Allergy Quality of Life Parental Burden (FAQL-PB)

A total of five studies were identified describing the development and validation of the FAQL-PB instrument (18, 26-29). It is a self-report on the parent or caregiver’s HRQL and contains 17 items and three domains.

One study focused on the creation and validation of a food allergy-specific HRQL instrument to measure parental burden associated with having a child with food allergy; the FAQL-PB (18).

The FAQL-PB was originally in English and was developed following item generation and item reduction (12-14, 17) resulting in a questionnaire with 17 items. The validation showed strong internal validity (Cronbach’s α = 0.95) and a good correlation with expectation of outcome questions (r = 0.412, p = <0.01). FAQL-PB was also able to demonstrate the ability to discriminate by disease burden; parents whose children had multiple (more than 2) food allergies were more affected than parents whose children had fewer allergies (scores, 3.1 versus 2.6, p = <0.001) (18).

One study reviewed the impact of pediatric food allergy on caregiver QOL (21). One study showed that mother
and child reported lower anxiety (p = 0.043 and p < 0.001) when the child was prescribed an epinephrine auto-injector (27).

One study tested the robustness of the Chinese food allergy QOL parental burden questionnaire (Chinese FAQL-PB). The internal validity of the instrument was excellent, (Cronbach’s α = 0.976 and an ICC = 0.701, p < 0.001). The authors did not use the FAIM tool to assess construct validity. However, confirmatory factor analysis (CFA) was undertaken to ensure that any domains found were genuinely present. The CFA revealed good correlations between the FAQL-PB items (28, 29).

**Food Allergy Quality of Life Questionnaire Parental Form (FAQLQ-PF)**

Four studies were reviewed for the development and validation of the FAQLQ-PF in this review (7, 15, 28, 30). The intended population is for parents of children aged 0 to 12 years with food allergy and is a proxy-report where parents report on their children’s HRQL. It contains 30 items and three domains. This instrument was developed, initially in English, as part of the EuroPrevall project and followed the development and validation method of the FAQLQ-CF, –TF and –AF.

The FAQLQ-PF was developed following item generation and item reduction (12-14, 17). Cross-sectional validity was assessed through evaluation of its construct validity, convergent and discriminant validity, discriminative ability and reliability.

One study revealed the design of a sensitive multidimensional measure to assess parental perception of HRQL in children aged 0 to 12 years. This was developed in four stages; internal consistency was moderate (Cronbach’s α > 0.7) for subscales and total score. Construct validity was demonstrated by significant correlations between relevant scales of the Child Health Questionnaire (CHQ)-28 and FAQLQ-PF subscales (r = 0.69 - 0.77, p < 0.01) and between FAQLQ-PF subscales and FAIM (r = 0.52 - 0.73, p < 0.001) (29).

One study compared child and parent proxy reports on HRQL in Dutch food allergic children (8–12 years old). Seventy-four child-parent pairs were included. The FAQLQ-CF score was significantly higher than the FAQLQ-PF score (3.74 versus 2.68, p < 0.001, where 1 indicates no impairment and 7 indicates extreme impairment). The internal consistency for the FAQLQ-PF (α = 0.95) and the construct validity was confirmed for the Dutch translation of the FAQLQ-PF (ρ = 0.58, p < 0.001) (7).

One study reviewed the validation of the FAQLQ-PF instrument in a French translation. The results demonstrated a strong correlation between FAQLQ-PF and FAIM (r = 0.85) and a good internal consistency (Cronbach’s α = 0.748) (15).

The fourth study assessed the longitudinal measurement properties of the FAQLQ-PF instrument. The results showed that domains and total score improved significantly at post-challenge time-points for both groups (all p < 0.05). Sensitivity was demonstrated by differences between positive and negative groups at six months [F (2, 59) = 6.221, p < 0.003] and by differing improvement on relevant subscales (p < 0.05). Minimally important difference (MID) was 0.45 on a seven-point response scale. Poorer QOL at baseline increased the odds by over 2.0 of no improvement in HRQL scores six-month time-point. The internal reliability of the overall score on the FAQLQ-PF (at six months) was found to be very good with a Cronbach’s α of 0.89 – 0.9 and the reliability of the change score (ICC of change) in the instrument subscales and total score ranged from 0.90 to 0.92 (30). Hence FAQLQ-PF is sensitive to change, and has excellent longitudinal validity and reliability in a food-allergic patient population.

**DISCUSSION**

**Principal findings**

This comprehensive systematic review has identified and formally appraised the underpinning evidence for available HRQL instruments for use in patients and parents of children with food allergy. We have found a number of instruments with good developmental and psychometric properties, and it is important that these are now widely used in research and clinical contexts. The inability at present to define a minimal clinically important difference remains a concern that needs urgently to be addressed, as does the need for making these instruments available in a wider range of European languages.

**Strengths and limitations**

The main strengths of this work include the use of formal systematic review methods, including the development of a formal systematic review protocol, which was
published in advance (11), and the involvement of a multi-disciplinary group of experts from a range of European countries.

The limitations of this work include the fact that our focus was on IgE-mediated food allergy (19), even though non-IgE-mediated and mixed IgE/non-IgE-mediated food allergy also occur and can have a profound impact on QOL. This decision, however, reflected the expert opinion that such instruments have yet to be developed; this therefore reflects an important outstanding research need.

In addition to Dutch and French, the FAQLQ-CF has been validated in English, Spanish and Polish (Goossens et al., submitted) and translated into nine other European languages. In addition to Dutch and English, the FAQLQ-AF has been validated in French, Greek, Icelandic, Italian, Polish, Spanish, Swedish (Goossens et al., in press) and translated into four other European languages. Also the FAQLQ-TF and – PF have been translated into a number of European languages and some of them are also validated (www.faqlq.com). A parent-administered instrument for adolescents (where parents report on their teenager’s HRQL) is under development in the UK (29). After the time period of the search of this review, the FAQL-PB was validated in the UK (31) and a new pediatric food allergy quality of life questionnaire (PFA-QL) was validated in the UK (33). Additionally, the development of the Pediatric Quality of Life Inventory Eosinophilic Esophagitis Module by Franciosi et al. is currently undergoing multi-centre field-testing, but this tool does not limit itself to IgE-mediated food allergy (34).

The time period of the search excluded an important study assessing longitudinal validity and responsiveness of the FAQLQ-AF, FAQLQ-TF, and FAQLQ-CF and the impact of a double-blind, placebo-controlled food challenge (DBPCFC) on HRQL (34). The results of the study demonstrated responsiveness of the FAQLQs through improved HRQL scores after a DBPCFC, with greater improvements in HRQL scores after a negative outcome (food allergy ruled out) than a positive outcome (food allergy confirmed). Additionally, longitudinal validity of these questionnaires was supported by significant correlations between the change (follow-up minus baseline) in FAQLQ and FAIM. FAQLQ-AF (Pearson correlation coefficient = 0.71, p<0.001), FAQLQ-TF (Pearson correlation coefficient = 0.35, p = 0.018), and FAQLQ-CF (Pearson correlation coefficient = 0.51, p<0.001) (34).

Interpretation of findings

The seven included HRQL questionnaires for food allergy were appraised as having relatively high quality of development properties (Table 3) and psychometric properties (Table 4). Regarding the development properties, the quality scores of the seven HRQL differed only slightly, ranging from 15 out of 18 (FAQl-teen) to 18 out of 18 (FAQLO-PF). For the psychometric properties, more variance was seen in the quality scores with the FAQl-teen having the worst score (5 out of 16) and the QAQLQ-PF having the best score (12 out of 16). For the adolescent age group, three questionnaires are available. The FAQLO-TF and the You and Your Food Allergy are comparable and have high quality development and psychometric properties. However, the FAQl-teen scored considerably lower on quality of psychometric properties and was specially developed for US adolescents which may limit its generalizability. It is also worth noting that cases of ‘excellent’ internal consistency (α>0.9), redundancy possibly exists and some items may be measuring very similar things. This might mean that the scale is capturing quite a narrow range of quality of life issues and/or could be made shorter without losing internal reliability.

When selecting an HRQL questionnaire, it is important to choose a questionnaire that is appropriate for the setting, diagnosis and age of the patient. In addition, it should be available in the appropriate language. Choosing the appropriate HRQL questionnaire in food allergic patients will be extensively discussed in the guidelines of the European Academy of Allergy and Clinical Immunology on Food Allergy HRQL measures (Chapter 3.2).

Implications for research, policy and practice

To date, none of the instruments developed have provided a clinical minimal important difference (MID). One instrument (FAQLO-PF) has ascertained the statistical MID, which is useful in deciding whether differences or changes are unlikely to be due to spontaneous variation in HRQL. It does not answer the question of whether patients find the difference or change in HRQL clinically important. This is therefore an unmet need in this area, as a clinical MID allow interventions to be assessed quantitatively by permitting calculation of numbers needed to treat
(NNT) resulting from the intervention being studied. Since non-IgE mediated food allergies are not the focus of this study and have not been studied, we anticipate the problems patients encounter to be quite different from those with immediate-type symptoms or anaphylaxis. So we cannot make any specific suggestions or predictions about the HRQL tools used for non-IgE mediated symptoms, suffice to say that the construction of any such instrument should adhere to the methodological principles of making a quality of life instrument.

Disease-specific, rather than generic QOL tools are necessary to provide an in-depth picture of the day-to-day concerns of patients, particularly in the context of long-term conditions. Disease-specific measures are also able to capture small but potentially important changes in HRQL that may occur as a result of clinical treatment and care. Disease-specific instruments also allow separation of the effects of an intervention on a target disorder from the effects on co-morbid conditions. Since many patients with food allergy also suffer from asthma, allergic rhinitis and/or atopic eczema/dermatitis, having disease-specific instruments for food allergy is particularly relevant in this regard.

Conclusions
This is the first review, to our knowledge, that has systematically assessed the literature on disease-specific QOL tools for food allergy. This systematic review demonstrated that there are a limited number of health-related QOL tools specifically for IgE-mediated food allergy. It is unlikely that the instruments described here will be useful for non-IgE mediated food allergy where the problems patients face are quite different. Healthcare workers should be aware of the impact of food allergy on an individual’s life and their families. Use of a HRQL questionnaire to evaluate HRQL in children, adolescent, adults with food allergy and their caregivers may be useful in clinical practice. For research purposes, use of properly validated instruments is critical to the accurate evaluation of HRQL in food allergic study participants.

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AS, AM, GR and AEJD conceived this review. It was undertaken by SAS with the support of AEJD, BMJF-deB, SP and SSP. SAS and AEJD led the drafting of the manuscript and all authors critically commented on drafts of the manuscript.

Conflicts of interest
None known

References


3.2

FOOD ALLERGY HEALTH-RELATED QUALITY OF LIFE MEASURES

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Instruments have been developed and validated for the measurement of health-related quality of life in patients with food allergy. These guidelines have been prepared by the European Academy of Allergy and Clinical Immunology’s (EAACI) Guidelines for Food Allergy and Anaphylaxis Group. It draws on a systematic review of the literature on quality of life instruments for food allergy and the Appraisal of Guidelines for Research & Evaluation (AGREE II) guideline development process. Guidance is provided on the use of such instruments in research and the current limitations of their use in clinical practice is described. Gaps in current knowledge as well as areas of future interest are also discussed. This document is relevant to health care workers dealing with food allergic patients, scientists engaging in food allergy research and policy makers involved in regulatory aspects concerning food allergy and safety.

BACKGROUND

In recent decades, food allergy has emerged as a significant medical problem throughout Europe (1). As the medical morbidity and mortality associated with food allergy is limited to symptoms resulting from incidental ingestions of allergenic foods, conventional, symptom-based outcome measures fail to reflect the ongoing burden of this condition to patients' well-being. Although health-related quality of life (HRQL) (Box 1) is an important outcome measure for many diseases, it is of particular importance for food allergy because there are no alternatives of sufficient sensitivity for use in most clinical situations. The relevance of HRQL measurement in allergy research, clinical practice and regulatory processes has been emphasized previously (2).

Scope and purpose of the guidelines

A number of studies have been undertaken in the last decade which broadly address the issue of quality of life in patients suffering from food allergy (3-9). Many of these studies have employed questionnaires designed to illuminate some aspect of the experience of patients with food allergy using both qualitative and quantitative approaches. These guidelines focus on instruments designed to measure HRQL in a quantitative and disease-specific fashion, and in particular, draws upon a systematic review of existing instruments, one of seven inter-linked evidence syntheses undertaken to provide a state-of-the-art synopsis of the current evidence base in this area (10). That review included a comprehensive search and quality assessment of instruments with special attention to the method of validation used. These guidelines examine the possible applications of these instruments and provides advice to clinicians and investigators on their proper use and interpretation of results. Current limitations will also be considered and gaps and areas of future interest identified.

METHODS

These guidelines were produced using relevant principles detailed in the Appraisal of Guidelines for Research & Evaluation (AGREE II) approach (11). This is in essence a structured approach to guideline production that is designed to ensure appropriate representation of the full range of stakeholders, a careful search for and critical appraisal of the relevant literature, a systematic approach to the formulation and presentation of recommendations, and steps to ensure that the risk of bias is minimized at each step of the process. We provide below an overview of the approach used.

Box 1  Key terms

<table>
<thead>
<tr>
<th>Health-related quality of life (HRQL): the impact of an illness and its therapy upon a patient, as perceived by the patient</th>
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<tbody>
<tr>
<td><strong>Validity</strong> is the degree to which an instrument measures what it is intended to measure. There are different types of validity of which construct validity is most important in HRQL measurement. <strong>Construct validity</strong> ensures that only that part of quality of life is being measured which is related to or driven by the disease in question. It is established by correlating measurements to one or more independent measures (IM) of the disease which provide an estimation of the extent and severity of patients' food allergy. An exact correlation is not expected as the HRQL instrument will not be measuring the same dimensions as the IM.</td>
</tr>
<tr>
<td><strong>Reliability</strong> includes reproducibility and internal consistency. <strong>Reproducibility</strong> ensures that measurements taken under identical conditions are equivalent, and may be assessed by test re-test analysis. It is generally assessed by asking patients to complete the HRQL instrument twice, a few weeks apart, during a period when there is no change expected in their HRQL (e.g. when they have not experienced any food allergic reactions or received any relevant interventions). <strong>Internal consistency</strong> ensures that the items of a questionnaire are related to each other and to the total questionnaire, and is usually assessed by Cronbach’s alpha.</td>
</tr>
<tr>
<td><strong>Responsiveness</strong> ensures that differences or changes of potential importance are not missed, and is examined by measuring differences or changes in groups where these are expected. It is often assessed in patients whose HRQL is expected to change (e.g. those who have experienced food allergic reactions or relevant interventions). <strong>Interpretability</strong> ensures that the relevance or clinical significance of measurements is apparent. This is ascertained by calculating the minimal clinically important difference (MCID), or the smallest change in HRQL score associated with a significant change in a global rating reported by patients.</td>
</tr>
</tbody>
</table>
Clarifying the scope and purpose of the guidelines

In January 2012, the scope of the intended guidelines was agreed upon, including the target allergy conditions and population, the end-user group and allowing for adequate academic, professional and lay presentation during guidelines development.

Ensuring appropriate stakeholder involvement

Participants represented a range of European countries, and academic and clinical backgrounds (including medical secondary care, primary care and nursing), and patient groups. The Food Allergy HRQL Taskforce continued to work together over the ensuing 18 months through email discussions, teleconferences and face-to-face meetings.

Systematic review of the evidence

The initial full range of questions that were considered important were rationalized through several rounds of iteration to agree to a single key over-arching question – namely, ‘Which disease-specific, validated instruments can be employed to enable assessment of the impact of, and investigations and interventions for, food allergy on HRQL?’ The answer to this was then pursued through a formal systematic review of the evidence (12) (see Chapter 3.1).

Formulating recommendations

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) (13) approach is a transparent, evidence-based approach to formulating recommendations for interventions and diagnostic tests. However, the GRADE approach is less suitable for use in the context of recommendations on the use of which quality of life instruments to select or how to use or interpret these. Therefore, following identification, critical appraisal and synthesis of relevant data, members of the Taskforce developed draft consensus recommendations on suitable validated instruments for use in the context of IgE-mediated food allergy, and the use of these instruments and interpretation of data for: (a) clinical and (b) research purposes.

Peer review

A draft of these guidelines were externally peer-reviewed by experts from a range of organizations, countries and professional backgrounds. In addition, these guidelines were posted on the EAACI website for public review for 3 weeks in June 2013. All feedback was considered by the Food Allergy HRQL Taskforce and, where appropriate, final revisions were made in the light of the feedback received. We will be pleased to continue to receive feedback on these guidelines, which should be addressed to the first author.

Identification of evidence gaps

The process of developing these guidelines has identified a number of evidence gaps and we plan in the future to prioritise the questions that the Food Allergy HRQL Taskforce believes should be most urgently addressed through formal consensus building techniques. We plan furthermore to draft outline research briefs that funders can use to commission research on these questions.

Editorial independence and managing conflict of interests

The production of these guidelines were funded and supported by EAACI. The funders did not have any influence on the guideline production process, its contents or on the decision to publish. Conflicts of interest statements were completed by all members of the Taskforce and these were taken into account by the Food Allergy HRQL Taskforce chair as recommendations were formulated.

Review of guidelines

The guidelines will be reviewed in 2017 and updated accordingly. However important advances will be incorporated prior to this date if required.

Results

The development of instruments used to measure HRQL should follow a specific methodology to ensure their validity, reproducibility, responsiveness (or sensitivity) and interpretability (3) (Box 1). All of these properties were examined in the systematic review (12) (Chapter 3.1). Particular emphasis was given to establishment of validity, which is of fundamental importance to proper instrument development.

Sixteen studies were quality appraised in the systematic review (12) and seven disease-specific HRQL instruments were identified as fulfilling the
criteria described above (4-8, 14-16). These included instruments for children, adolescents, adults and parent or caregiver, and were either self-reported or proxy-reported (see Table 1).

The Food Allergy Quality of Life Questionnaire (FAQLQ-CF, -TF, -AF and -PF) instruments have undergone the most thorough validation process, including assessment of their psychometric properties. These FAQLQs are available free of charge and several are available in multiple languages (www.faqlq.com).

### Choosing an instrument

If HRQL instruments are to yield useful information in patients with food allergy, it is important to choose a tool that is appropriate for the setting, diagnosis and age of the patient (3, 17). Food allergy-specific HRQL questionnaires (Table 1) have been developed and validated for patients with IgE-mediated allergies (excluding Oral Allergy Syndrome (OAS)) and are therefore not suitable for non-IgE mediated food allergies. The food allergy-specific HRQL instruments have been designed to detect clinically important differences and changes in the disease-specific quality of life of patients with food allergy. As they are specific for IgE-mediated food allergy, they do not allow for comparison with other disorders.

The choice of food allergy-specific HRQL instrument should primarily be determined by the age of the patient, as highlighted in Table 1. In young children (i.e. those ≤8 years), a parent proxy questionnaire (which can be used up to the age of 12 years) is required (7, 8) whereas patient-administered instruments are appropriate for older children (>8 years) (4), adolescents (5, 15, 16) and adults (6), as they can express their own social/emotional and physical well-being. Language may also impact on the choice of instrument, not only because of differences between languages, but also because of cultural differences in various areas where the same language is spoken. The FAQLQ-AF has now been validated in several European countries and is available in English (18, 19), French, Spanish, Italian, Polish, Greek, Dutch and Icelandic (19). The FAQLQ-PF has been validated in French, Spanish, German, Dutch, Danish and Mandarin, although only the data on the first has been published in a full length paper to date (20). Also the FAQLQ-CF has also been translated and validated into a number of European languages (21). The FAQL-teen, FAQL-PB and You and Your Food Allergy questionnaire are only available in the language of development (English).

### Table 1 Summary of food allergy specific health related quality of life instruments

<table>
<thead>
<tr>
<th>Abbreviation (where stated)</th>
<th>Key reference</th>
<th>Full name</th>
<th>Target population (age range in years)</th>
<th>Respondent (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAQLQ-CF</td>
<td>4</td>
<td>Food Allergy Quality of Life Questionnaire -Child Form</td>
<td>Children (8 to 12)</td>
<td>Children (8 to 12)</td>
</tr>
<tr>
<td>FAQLQ-TF</td>
<td>5</td>
<td>Food Allergy Quality of Life Questionnaire -Teenager Form</td>
<td>Adolescents (13 to 17)</td>
<td>Adolescents (13 to 17)</td>
</tr>
<tr>
<td>FAQL-teen</td>
<td>15</td>
<td>Food Allergy Quality of Life Assessment Tool For Adolescents</td>
<td>Adolescents (13 to 19)</td>
<td>Adolescents (13 to 19)</td>
</tr>
<tr>
<td>You and Your Food Allergy</td>
<td>16</td>
<td>You and Your Food Allergy</td>
<td>Adolescents (13 to 18)</td>
<td>Adolescents (13 to 18)</td>
</tr>
<tr>
<td>FAQLQ-AF</td>
<td>6</td>
<td>Food Allergy Quality of Life Questionnaire -Adult Form</td>
<td>Adults (≥18)</td>
<td>Adults (≥18)</td>
</tr>
<tr>
<td>FAQL-PB</td>
<td>14</td>
<td>Food Allergy Quality of Life - Parental Burden</td>
<td>Parents</td>
<td>Parents</td>
</tr>
<tr>
<td>FAQLQ-PF</td>
<td>7</td>
<td>Food Allergy Quality of Life Questionnaire - Parent Form</td>
<td>Children (0 to 12)</td>
<td>Parents</td>
</tr>
</tbody>
</table>
2012), another disease-specific instrument has been validated in the UK for children with food allergy and their parents: the Paediatric Food Allergy Quality of Life Questionnaire (PFA-QL) (22). In addition, the FAQLQ-CF, -TF and -AF were shown to be longitudinally valid and responsive (23).

Currently, there are no tools that can be used to gain insight on the contribution of the parent-child relationship on the HRQL of a food allergic child. There is some evidence that comparison of patient reported HRQL to parent (proxy) reported HRQL using the FAQLQs can offer some insights in this area (24, 25). In addition, an optional section in the FAQLQ-PF evaluates the amount of stress felt by mother, father, and family as a result of food allergy. Self-reported level of stress has been found to correlate significantly with

**Box 2** Summary box of factors to take into account when choosing a HRQLQ for food allergy

- Type of food allergy (IgE mediated or not, OAS)
- Research or clinical application
- Inclusion or exclusion of effects of co-morbidities
- Patient age
- Language and cultural availability/appropriate-ness
- Preferred respondent: parent/caregiver as proxy, or child
- Target population/individual: parent/caregiver or child
parent rated HRQL for the child (26). A parent (proxy) reported instrument is currently being developed for adolescents with food allergy which may increase our knowledge of the role that adolescent-parent relationships play in teenagers with food allergy. Finally, the dynamics of a family with a food allergic child may also be informed by assessing the parental burden using the FAQL-PB (14).

Currently, the FAQLQs have only been used in the research setting to provide quantitative information on the HRQL of patients with IgE-mediated food allergy, to assess the effect of interventions and determine outcomes (3). If they are to be used in clinic, the question arises as to whether they are a valid measure of HRQL at the level of individual patients and suitable to guide clinical practice. Methods to assess individual validity and patient acceptability of HRQL have been used in other diseases (27, 28). In essence, to be useful in clinical practice, reproducibility of the HRQLQ is required to be high and sensitive enough to detect the effects of differences in allergy management. In addition, the HRQLQ should be simple, easy to score and interpret and the information the instrument provides must be shown to affect patient management (29). Although the instruments described in these guidelines have characteristics suggesting they may be capable of providing valid HRQL assessments at the level of individual patients, more studies are required in this area. One recent study (30) evaluated the effectiveness of a developmentally appropriate cognitive behavioural therapy (CBT) intervention specifically developed to improve HRQL for children and teenagers with IgE mediated food allergy. The FAQLO-PF, CF, and TF were used and the results showed that the measures were sensitive enough to detect improvement in HRQL in individual patients relative to a control group.

For patients with food allergy outside the remit of current validated food allergy-specific HRQLQ (e.g. those with non-IgE mediated food allergy or OAS) validated, generic HRQL questionnaires may be considered. However, these have not been designed to detect HRQL issues specific to food allergy and so are unlikely to be sensitive to small but potentially important differences or changes in food allergy HRQL. Moreover, generic HRQL questionnaires will be affected by any existing comorbid disorders. Another possibility, is to use a food allergy-specific HRQLQ and administer an appropriate independent measure of disease severity simultaneously in order to check the validity of this questionnaire in another population (e.g. non-IgE mediated food allergy or OAS).

Using an instrument

Ideally, HRQL instruments should be used in the setting (language, culture and age group) in which it was developed. In practice, instruments must often negotiate differences between the setting of their development and their ultimate application. It is thus often advisable to include an independent measure such as the Food Allergy Independent Measure (FAIM) (31) in the study in the new setting. Such a measure should be available in the same language and may help to differentiate between negative study outcomes due to lack of changes in HRQL from those due to loss of validity of the HRQL measure in the new setting.

HRQL measurements are imminently suited to determine whether interventions offer a benefit increment to patients which they find meaningful. In order to demonstrate this, the minimal clinically important difference (MCID) for the instrument used must be determined. The MCID is the smallest increment of difference or change in HRQL score which patients find clinically meaningful. Currently, none of the food allergy instruments have provided a MCID. This is thus an unmet need in this area, as it will allow interventions to be assessed quantitatively by permitting calculation of numbers needed to treat (NNT) resulting from the intervention studied.

Pharmaco-economic research is mostly used to identify, measure, and compare the costs, risks, and benefits of programs, services, or therapies and determine which alternative produces the best health outcome for the resources invested. Validated HRQL instruments for food allergy can be of value because they are able to measure the benefits of health care interventions from a patient perspective and ascertain whether the benefit of a particular intervention justify the resources required. Such measurements may be expressed as Quality-Adjusted Life Years (QALYs) that capture both the HRQL lost or gained and the time to which this change pertains. Such information is essential to cost-utility analyses which are important to policy makers.

Aside from the FAIM or similar independent measure and a global assessment, many other psychometric tools may be used concomitantly to gain insight into
the patient experience of disease and treatment. Of these, the burden of treatment (BoT) measurement deserves special mention, as it allows the evaluation of disease and treatment by asking patients to weigh these entities in their overall assessment of the benefits of a particular intervention. Together with HRQL, this can offer a comprehensive evaluation of the net benefits of an intervention.

The use of food allergy HRQL questionnaires to measure effect of interventions on HRQL of food allergic patients is increasing. Outcomes of these studies are described in the EAACI guidelines on diagnosis and treatment of food allergy (32).

GAPS IN THE EVIDENCE AND RECOMMENDATIONS

The healthcare system has traditionally focused on treating disease at point of failure, such as life-saving surgery or intensive medical therapy. In the case of food allergy, this occurs with accidental reactions and/or anaphylaxis. With health care professionals and governments now placing more of an emphasis on prevention, a different patient management model is required to assess cost-effectiveness within the continuum of care. Clinically, standardized HRQL measures can enhance screening patients for burdens associated with even asymptomatic periods of food allergy and can be used to monitor changes. Therefore, the development of high quality food allergy-specific HRQL instruments is a welcome advance in helping to assess the impact of IgE-mediated food allergy on patients’ quality of life. That said, it is important to note that there remain a number of important research gaps in order to have a comprehensive set of tools for use in the everyday management of patients with food allergy across Europe. These are summarized below.

First, the MCID of existing instruments needs to be determined. This is essential to allow for calculation of NNT for clinical care and pharmaco-economic analysis. Second, there are at present no tools for assessing HRQL in those with non-IgE-mediated food allergy or in those with OAS. Given that these manifestations of food allergy can have a substantial impact on the quality of life of patients and carers, there is a pressing need to develop appropriate instruments.

Third, the tools available for assessing HRQL in those with IgE-mediated food allergy are still only available in a fraction of the languages spoken across Europe. Given that food allergy affects people throughout Europe, formal validational work needs to be undertaken to make these instruments available across the full spectrum of relevant languages.

Fourth, how best to develop an efficient and integrated method of assessment and monitoring of HRQL in patients with co-existent allergic problems has been a matter of recent debate. In order to retain the advantages of a disease specific instrument, the use of information and communications technology may be an option. Unlike a paper questionnaire, electronic questionnaires can be developed that consist of a subgroup of questions from a much larger collection to provide personalised instruments that, for example, cater for type of allergy, multiple allergy, distance from medical centre, or co-morbid condition. Where appropriate, section(s) on coping, anxiety, risk, reactions, and management style could also be included. In addition, as electronic questionnaires could facilitate implementation in routine care contexts, it is important that these tools are validated for use across a range of platforms – for example, completion on patient portals, mobile phones, tablets, and personal computers. Given the increasing move to electronic health records across Europe (33), electronic data capture will also facilitate seamless transfer into patient records. A further advantage of an electronic system would be the ease with which a detailed database could be generated for health status of individual patients on a longitudinal basis. This would allow healthcare providers to target additional input to individual patients or families experiencing impaired HRQL due to particular circumstances.

Fifth, it should be noted that the available instruments have primarily been developed for use in research contexts. Using instruments in routine clinical contexts is potentially very valuable and is hence on the policy agendas of some European countries, but this does require the MCID of the instruments to be established in order to assess the impact of interventions/care provision on individual patients.

Sixth, how best to assess HRQL in the many patients with co-existent allergic problems is another related clinically important consideration. The main options are to either use an accompanying generic instrument (e.g. the EQ-5D) or to add in additional disease specific instruments for each co-morbidity. Whilst the
latter approach may be feasible in those with one co-morbidity (e.g. atopic eczema/dermatitis), it is likely to prove much more challenging in those with multiple co-morbidities (e.g. atopic eczema/dermatitis, allergic rhinitis and asthma).

Finally, efforts to link quality of life gains and optimal resource allocation has proved challenging in many areas of healthcare. However, how HRQL can aid policy decisions in allocating healthcare resources is an important issue for policy makers. Decisions are often taken based on the outcomes of an evaluation expressed as incremental costs per QALY gained, or disability-adjusted life years (DALY). Measuring HRQL in economic or monetary terms has not been attempted to date in the area of food allergy. Since QALYs need to be measured against some threshold (usually the monetary or consumption value of QALY gains), disease-specific, meaningful estimates of the value of QALY gains in food allergy need to be developed. Disease specific HRQL measures can be a key tool in such a development. Therefore, there is a need to identify relevant thresholds for costs per QALY and how these might vary across Europe in order to help inform policy considerations. In this respect, it is important that individual, family and societal perspectives are considered.

Based on the systematic review of HRQL instruments for IgE mediated food allergy, and the identification of needs and gaps in clinical practice and research, we make the following recommendations. These can be divided into general recommendations (Box 3), recommendations for clinicians (Box 4) and recommendations for research (Box 5).

**Where next with HRQL instruments?**

Some questions remain that impact on the future potential value of HRQL measures in allergy. Firstly, what are the correlates of HRQL in food allergy (e.g. anxiety, health beliefs, risk perception, information processing, coping behaviours) and how do they impact on the likelihood of adverse reactions and management? Which of these variables are causally related to HRQL status, and which variables are the effect of HRQL status? Lastly, as HRQL depends on subjective perception of the burden of food allergy, what are the underlying neuropsychological mechanisms (e.g. stress/immune interactions)? These questions have particular relevance for the interpretation and usefulness of HRQL measures in clinical practice. As our knowledge base grows, clarity will evolve about

**Box 3 General recommendations**

1. Only validated instruments as identified by this systematic review should be used to measure HRQL in food allergic subjects.

2. An independent measure (e.g. FAIM) should be used simultaneously as a correlating measure.

3. An established approach should be used when the validated questionnaires are translated into other languages, e.g. back translation and validation in the local language – there may be important linguistic or cultural issues that invalidate the tool in other countries.

4. To date, the FAQLQ (AF, TF, CF and PF) and FAQL-PB and –teen instruments and the You and Your Food Allergy instrument are the only tools sufficiently well-validated to be used in research contexts. The appropriate questionnaire will depend on the age of the patient.

5. Alterations to questions in the instrument are strongly discouraged, as these may compromise validity. If alterations are made, the instrument requires re-validation.

6. The instruments recommended in this review are specific to IgE-mediated food allergy and are not suited for use in patients with non-IgE mediated disease or oral allergy syndrome. Furthermore, for patients where measurement of HRQL due to comorbid conditions is desireable, appropriate disease-specific and/or a generic instrument may be required.

**Box 4 Recommendations for clinicians**

1. To date, the use of food-allergy specific HRQL tools in clinical practice has been little documented. Clinicians should be aware of this and be cautious when using HRQL measurements to guide management decisions.

2. There is currently also no information on the use of HRQL measurements as a form of bench-marking in food allergy.
how HRQL relates to other variables. Studies must be theory driven, well designed, multi-site, and build on previous work. It is important that we design studies that help to clarify the physiological mechanisms that underlie the psycho-social predictor and outcome variables in our models. For example, models should allow for bidirectional and causal pathways linking health to HRQL (including all significant variables and their weights). If the flow is bi-directional for some of the components, this has profound implications in terms of interpretation and application of HRQL results. The mechanisms responsible for any associations should be evaluated. Such models may be seen as a blueprint for exploration as well as a summary of available evidence.

Since the developmental process plays an important role in shaping and determining physical and psychological health and HRQL, an attempt to delineate a developmental pathway is also vital. Life transitions provide a naturalistic research opportunity to investigate adaptability to a diagnosis of food allergy and the link to health outcomes and HRQL. The pathway should take account of sensitive transition points when the interaction of biopsychosocial factors may create an increased vulnerability in terms of health and well-being (9, 34).

In addition to providing a meaningful way to assess the end results of health care services, including clinical and therapeutic interventions, and policy, HRQL measures can allow health professionals to pinpoint the time when both parents and children may need further support on issues such as diet, auto-injectors, risk management, managing anxiety, and changing developmental and practical challenges. It can also help us to identify unintended impacts of potential management options. The use of HRQL measures cross-culturally and across countries can delineate similarities, differences, and dynamic factors. Taken together, such findings, combined with research on variables related to HRQL, can provide a broader view than has hitherto often been the case on the impact of food allergy.

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**Authors’ contribution**

Antonella Muraro, Chair of the EAACI Food Allergy and Anaphylaxis Guidelines Initiative, has steered and coordinated the publication. Anthony Dubois facilitated the guidelines group and edited the guidelines document. Bertine Flokstra-de Blok facilitated the identification of research questions for the systematic review and processed the feedback of the experts. Anthony Dubois, Audrey DunnGalvin, Rosan Meyer, Nicolette de Jong, Aziz Sheikh, Allison Worth and Bertine Flokstra-de Blok drafted specific sections. Sarah Salvilla and Sukhmeet Panesar undertook the supporting systematic review under the supervision of Aziz Sheikh. All authors participated in the discussion of the sections, recommendations, gaps and approved the final version.
Conflicts of interest

Antonella Muraro has provided scientific advice for Meda. Anthony Dubois has provided scientific advice for ALK-Abello and received funding from ALK Abello to support his research activities. Audrey DunnGalvin has received funding from Novartis for her research. Jonathan O’B. Hourihane has received speaker fees from Mead Johnson, Nutricia, MSD, Pfizer, ALK-Abello and Stallergenes; Thermo Fisher have provided consumables for his research activities. Nicolette W de Jong has no conflict of interests. Rosan Meyer has provided scientific advice for Danone, Nestle and Mead Johnson. Graham Roberts has provided scientific advice for Danone and ALK-Abello; Thermo Fisher and ALK-Abello have provided consumables for his research activities. Aziz Sheikh has provided scientific advice to ALK-Abello, Meda, Lincoln Medical, Thermo Fisher, Pfizer and Stallergenes; he is on the Anaphylaxis Campaign UK’s Scientific Committee, World Allergy Organization’s Anaphylaxis Special Committee, UK Resuscitation Council’s Anaphylaxis Committee and the BSACI’s Standard of Care Committee and has received funding for coordinating guideline production, and generating the systematic reviews from EAACI. Sarah Salvillaand Sukhmeet Panesar have no conflict of interest. Allison Worth has received funding from ALK Abello, Meda and ThermoFisher to attend meetings and provide professional education. Bertine Flokstra-de Blok has no conflict of interest.

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4.1

THE EPIDEMIOLOGY OF ANAPHYLAXIS IN EUROPE

SYSTEMATIC REVIEW

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**Background:** Anaphylaxis is an acute, potentially fatal, multi-organ system, allergic reaction caused by the release of chemical mediators from mast cells and basophils. Uncertainty exists around epidemiological measures of incidence and prevalence, risk factors, risk of recurrence and death due to anaphylaxis. This systematic review aimed to: (1) understand and describe the epidemiology of anaphylaxis; and (2) describe how these characteristics vary by person, place, and time.

**Methods:** Using a highly sensitive search strategy, we identified systematic reviews of epidemiological studies, descriptive and analytical epidemiological investigations and studies involving analysis of routine data.

**Results:** Our searches identified a total of 5843 potentially eligible studies, of which 49 satisfied our inclusion criteria. Of these, three were suitable for pooled estimates of prevalence. The incidence rates for all-cause anaphylaxis ranged from 1.5 to 7.9 per 100000 person-years. These data indicated that an estimated 0.3% (95% CI 0.1, 0.5) of the population experience anaphylaxis at some point in their lives. Food, drugs, stinging-insects and latex were the most commonly identified triggers.

**Conclusions:** Anaphylaxis is a common problem; affecting an estimated 1 in 300 of the European population at some time in their lives. Future research needs to focus on better understanding trends across Europe and identifying those most likely to experience fatal reactions.

Epidemiology of anaphylaxis in Europe

BACKGROUND

Anaphylaxis is a ‘severe, life-threatening generalised or systemic hypersensitivity reaction’. Several working definitions of anaphylaxis have been formulated to aid diagnosis and management (1-4). The most well-known is the consensus clinical definition proposed by Sampson et al., which involved representatives of a number of international allergy organisations, including the European Academy of Allergy and Clinical Immunology (EAACI) (Box 1) (5).

With anaphylaxis being a syndrome with variable symptoms, signs, and time course, none of the definitions are ideal and impede accurate epidemiological study (6). Additionally, the acute onset and transient nature renders it difficult to mount prospective investigations (7). Notwithstanding these inherent challenges, there is a need to improve our understanding of the epidemiology of anaphylaxis to understand the overall disease burden posed by the condition and obtain insights into its etiology, risk stratification and prognosis. Epidemiological measures of particular interest for anaphylaxis therefore include measures of incidence and prevalence, risk factors, and risk of recurrence and death (8) (Box 2). Other aspects of interest concern features of persons who experience anaphylaxis, temporal relationships, and the factors that lead to its development and recurrence (9).

This systematic review is one of seven inter-linked

### Box 1 Clinical criteria for diagnosing anaphylaxis

<table>
<thead>
<tr>
<th>Anaphylaxis is likely when any 1 of the 3 criteria are fulfilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Acute onset of an illness (minutes to hours) with involvement of</td>
</tr>
<tr>
<td>Skin/mucosal tissue (e.g. hives, generalized itch/flush, swollen lips/tongue/uvula)</td>
</tr>
<tr>
<td><strong>AND</strong></td>
</tr>
<tr>
<td>Airway compromise (e.g. dyspnea, wheeze/bronchospasm, stridor, reduced peak expiratory flow (PEF))</td>
</tr>
<tr>
<td><strong>OR</strong></td>
</tr>
<tr>
<td>Reduced BP or associated symptoms (e.g. hypotonia, syncope)</td>
</tr>
<tr>
<td>(2) Two or more of the following after exposure to known allergen for that patient (minutes to hours)</td>
</tr>
<tr>
<td>History of severe allergic reaction</td>
</tr>
<tr>
<td>Skin/mucosal tissue (e.g. hives, generalized itch/flush, swollen lips/tongue/uvula)</td>
</tr>
<tr>
<td>Airway compromise (e.g. dyspnea, wheeze/bronchospasm, stridor, reduced peak flow)</td>
</tr>
<tr>
<td>Reduced blood pressure (BP) or associated symptoms (e.g. hypotonia, syncope)</td>
</tr>
<tr>
<td>In suspected food allergy: gastrointestinal symptoms (e.g. crampy abdominal pain, vomiting)</td>
</tr>
<tr>
<td>(3) Hypotension after exposure to known allergen for that patient (minutes to hours)</td>
</tr>
<tr>
<td>Infants and children: low systolic BP (age-specific) or &gt;30% drop in systolic BP*</td>
</tr>
<tr>
<td>Adults: systolic BP &lt;100 mm Hg or &gt;30% drop from their baseline</td>
</tr>
</tbody>
</table>

Reproduced with permission from Sampson et al. (5) (C). *Low systolic BP for children is defined as <70 mm Hg from 1 month to 1 year; less than (70 mm Hg + [2 × age]) from 1 to 10 years; and <90 mm Hg from age 11 to 17 years.

### Box 2 Epidemiological definitions

<table>
<thead>
<tr>
<th>Incidence: The number of new cases of anaphylaxis that occur during a given period in a defined population. Incidence will be studied as:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• <strong>Incidence rate</strong>: The number of new cases of anaphylaxis that occur during a defined period per unit person-time.</td>
</tr>
<tr>
<td>• <strong>Cumulative incidence</strong>: The number of new cases of anaphylaxis that occur during a given period per the population at risk.</td>
</tr>
<tr>
<td><strong>Prevalence</strong>: The proportion of a defined population known to have experienced anaphylaxis. Care is required in defining the appropriate denominator. This epidemiological measure will be further divided into:</td>
</tr>
<tr>
<td>• <strong>Point prevalence</strong>: the proportion of the population that has experienced anaphylaxis at a specific time</td>
</tr>
<tr>
<td>• <strong>Period prevalence</strong>: the proportion of the population that has experienced anaphylaxis during a given period</td>
</tr>
<tr>
<td>• <strong>Lifetime prevalence</strong>: the proportion of the population that at some point in their life will have experienced anaphylaxis.</td>
</tr>
<tr>
<td><strong>Case fatality rate</strong>: The proportion of cases of anaphylaxis that proves fatal (usually defined within a time period). This is also sometimes known as the case fatality ratio.</td>
</tr>
</tbody>
</table>

Definitions based on those proposed by Last (8).
evidence syntheses that have been undertaken to provide a state-of-the-art European synopsis of the current evidence base in relation to epidemiology, prevention, diagnosis and clinical management, and impact on quality of life. This will be used to inform clinical recommendations within the EAACI Guidelines for Food Allergy and Anaphylaxis.

AIMS

The aims of this systematic review were to: (1) understand and describe the epidemiology of anaphylaxis, i.e. frequency, risk factors, and outcomes of anaphylaxis; and (2) describe how these characteristics vary by person, place, and time.

METHODS

The protocol of this review has been published previously (10) and it is registered with the International Prospective Register of Systematic Reviews (PROSPERO; http://www.crd.york.ac.uk/prospero/, reference CRD42013003702).

Search strategy

A highly sensitive search strategy was designed (see Boxes E1-4 in supplementary material) to retrieve all articles combining the concepts of anaphylaxis and epidemiology from electronic bibliographic databases. We conceptualised the search to incorporate the three elements below as shown in Figure 1.

Inclusion criteria for study design

The following studies were included: systematic reviews +/-meta-analyses, cohort studies, cross-sectional studies, case-control studies and routine healthcare studies. These were chosen to ensure that the highest levels of evidence were pooled based on the aims of this review (11).

Exclusion criteria for study design

Reviews, discussion papers, non-research letters and editorials, case studies, and case series plus animal studies were excluded.

Study selection

The titles of the retrieved articles were checked independently by two reviewers (SSP, DdS) according to the selection criteria and categorised as: included, not included and unsure. The abstracts of unsure category papers were retrieved and they were re-categorised after discussion. Any discrepancies were resolved by consensus and, if necessary, a third reviewer (AS) was consulted to arbitrate. Full text copies of potentially relevant studies were obtained and their eligibility for inclusion assessed.

Quality assessment strategy

Each study was quality assessed independently by two reviewers (SSP, HH) using the relevant version of the Critical Appraisal Skills Programme (CASP) quality assessment tool for systematic reviews, (12) cohort

Figure 1 Conceptualisation of systematic review of the epidemiology of anaphylaxis
studies (13) and case-control studies (14) which involved an assessment of internal and external validity (15). Similarly, we used the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for assessing other forms of quantitative studies such as cross-sectional studies and routine healthcare studies (16). Any discrepancies were resolved by discussion or, where necessary, by arbitration by a third reviewer (AS).

Analysis, data synthesis and reporting
Data were independently extracted onto a customised data extraction sheet by two reviewers (DdS, SSP), any discrepancies were resolved by discussion or, were necessary, by arbitration by a third reviewer (AS). A descriptive summary with data tables was produced to summarise the literature. Meta-analysis was undertaken using random-effects modelling and adopting methods suggested by Agresti and Coul. Heterogeneity was assessed using Cochrane’s Q, a statistic based on the chi-square test with corresponding Z- and p-values. As this test is known to have low power, the I2 statistic was also calculated: a value of 25% corresponds to low heterogeneity, 50% to moderate and 75% to high (17). Comprehensive Meta-Analysis (Biostat, Englewood, NJ) was used for these analyses. A narrative synthesis of the data was also undertaken. The PRISMA checklist was used to guide the reporting of the systematic review (see Box E5) (18).

RESULTS
Overview of results
The searches identified a total of 5843 potentially eligible studies, of which 49 satisfied our eligibility criteria and were therefore included in this review (see Figure 2) (19-67). The key characteristics and main findings of all included studies are detailed in Table E1 and the quality assessment of these studies is summarised in Table E2. The main findings are further discussed in more detail below.

Incidence, prevalence and trends over time
Incidence
Ten studies offered varying estimates of incidence rates as shown in Table E1 (24, 31, 44, 50-52, 56-59). These ranged from 1.5 per 100000 person-years (24) to 32 per 100000 person-years (45). In one study, over a four-year period, anaphylaxis was the cause of 0.1% of children’s hospital admissions and 0.3% of adult admissions (50). Pooled analysis was not possible due to the heterogeneity of the populations and the different approaches to reporting incidence in these studies.

Prevalence
The descriptions used in studies typically failed to differentiate clearly between measures of point, period and lifetime prevalence. Quantitative data were available for pooling from three population-based studies (26, 39, 57); in which estimates of prevalence ranged from 1/1333 (0.1%) (57) to 37/6676 (0.6%) (39). Meta-analysis (I2 = 99.9%) yielded a pooled prevalence estimate of 0.3% (95% CI 0.1 to 0.5), as shown in Figure 3.

Variations by person, place and time
Person: In a study of 325046 people, a peak incidence of 313.58 per 100000 person-years was noted in the 0–4 years old group; this was significantly different (p<0.05) to other age groups. For affected people over 10 years of age, incidence tended to be higher for females (58). A review of 816/401152 (0.2%) ambulance calls for anaphylaxis found that 180/816 (22%) involved children (26). Secondary analyses of various healthcare databases found that 4.1 per 100000 admissions to hospitals were in the 0–14 years group, 3.9 per 100000 in the 15–44 years group and 3.5 per 100000 in the 45 years and older group (52).

Place: The study by Sheikh et al. reviewed 13.5 million emergency hospital admissions (2323 for anaphylaxis) over a five-year period. A north-south divide existed in the UK with a higher frequency of anaphylaxis admissions in the south (rate ratio 1.35, 95% CI 1.25 to 1.47). A rural to urban rate ratio of 1.35 (95% CI 1.17 to 1.59) and a non-deprived to deprived rate ratio of 1.32 (95% CI 1.19 to 1.46) were also noted (56).

Time: Increases in the incidence rate of anaphylaxis have been reported (44, 51, 57). The incidence of hospital admissions for anaphylaxis increased from 5.6 per 100000 discharges in 1991-92 to 10.2 per 100000 discharges in 1994-95 (44). Age-sex standardised incidence was estimated as 6.7 per 100000 person-years in 2001, rising to 7.9 per
Figure 2 PRISMA diagram for epidemiology of anaphylaxis

Studies included in qualitative synthesis (n = 49)

Records excluded (n = 5459)

Full-text articles excluded (list of studies in Appendix 1):
  • Pre-year 2000 or post year 2012 (n = 20)
  • Outside Europe (n = 86)
  • Study design unable to yield chosen outcomes (n = 14)

Full-text articles assessed for eligibility (n = 169)

Records screened (n = 5628)

Records identified through database searching (n = 5829)

Additional records identified through other sources (n = 14)

Duplicates (n = 215)

Records excluded (n = 5459)

Figure 3 Pooled estimate for the prevalence of anaphylaxis

<table>
<thead>
<tr>
<th>Study</th>
<th>Events</th>
<th>Total</th>
<th>Proportion</th>
<th>95%-CI</th>
<th>W(random)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capps JA 2010</td>
<td>816</td>
<td>401152</td>
<td>0.00020</td>
<td>[0.0019; 0.0022]</td>
<td>42.9%</td>
</tr>
<tr>
<td>Quercia O 2012</td>
<td>37</td>
<td>6676</td>
<td>0.0055</td>
<td>[0.0039; 0.0076]</td>
<td>41.1%</td>
</tr>
<tr>
<td>Shiekh A 2008</td>
<td>1</td>
<td>1333</td>
<td>0.0008</td>
<td>[0.0000; 0.0042]</td>
<td>16.0%</td>
</tr>
<tr>
<td>Random effects model</td>
<td>409161</td>
<td></td>
<td>0.0026</td>
<td>[0.0010; 0.0070]</td>
<td>100%</td>
</tr>
</tbody>
</table>

Heterogeneity: I-squared=94.6%, tau-squared=0.5911, p<0.0001
100000 person-years in 2005 (57). Anaphylaxis rates rose from 6 to 41 per million admissions between 1990-91 and 2000-01 (51). On a similar note, the lifetime age-sex standardised prevalence of recorded diagnosis of anaphylaxis was 50 per 100000 in 2001, rising to 75.5 per 100000 in 2005 (57).

### Triggers (elicitors) and co-morbidities

The key triggers identified in these studies included foods, medications, stinging insects and latex. Co-morbidities such as atopic eczema/dermatitis and asthma were also found to be important (30). For example, in a case-control study of co-existing asthma, atopic eczema/dermatitis was the only factor associated with a significantly increased risk of anaphylaxis within the asthma free cohort (odds ratio (OR) 2.83, 95% CI 1.51 to 5.29). Within the cohort with asthma, the following co-morbidities were associated with increased occurrence of anaphylaxis: allergic rhinitis (OR 1.76, 95% CI 1.35 to 2.30), atopic eczema/dermatitis (OR 1.69, 95% CI 1.13 to 2.51) and osteoarthritis (OR 1.50, 95% CI 1.05 to 2.14) (30).

### Food triggered reactions

The proportions of food allergy reactions that resulted in anaphylaxis varied markedly (28, 32, 41, 46, 64), 67 with estimates ranging from 12/2716 (0.4%) (41) to 65/163 (39.9%) (Table E1) (64). Different estimates of the most frequent food allergens implicated in anaphylaxis have been provided by the studies. For example, peanuts and tree nuts (27.6%), hen’s egg (8.6%) and foods cross-reacting with latex (11%) were the most commonly identified food triggers in one study (64). The food allergens that most commonly resulted in anaphylaxis in another study of 163 children were cow’s milk (47/163, 29%), hen’s egg (25/163, 25%), hazelnut (9/163, 5%), peanut (6/163, 4%), kiwi (7/163, 4%), walnut (6/163, 4%), pine nut (5/163, 3%), fish (5/163, 3%), wheat (4/163, 2%), soy (3/163, 2%), shrimp (3/163, 2%), apricot (3/163, 2%) and sesame (3/163, 2%) (28). Exposure to airborne allergens increased the risk of anaphylaxis due to food with children with pollen allergy being at increased risk of being admitted with food-related anaphylaxis during the pollen season (46).

### Medication and therapeutic agent triggered reactions

The systematic review by Nybo et al. (2008) (36) included 25 studies, only two of which met our inclusion criteria (35, 54). Five studies provided estimates for medication-triggered anaphylaxis, (22, 23, 33, 36, 48, 69) which ranged from 3/1446 (0.2%) (33) to 3 of 96, 3.1% (22). There was wide variation in the frequency of anaphylaxis associated with different medications. For example, the rate per 100000 exposed cases was 2.1 for aspirin, 32.0 for parenteral penicillin, and 378.0 for parenteral plasma. These plasma reactions are considered to be infusion reactions rather than true cases of anaphylaxis. There was a relatively low risk for dipyrone, diclofenac, paracetamol, ampicillin, cloxacillin, and cephalosporins. In contrast, parenteral penicillin, dextran, contrast media, blood, and pentoxifylline were associated with intermediate risks. The highest incidences were observed in those receiving plasma and streptokinase (34). However, given the diverse nature of the studies, it is difficult to make conclusions on the true frequency of anaphylaxis in this category.

### Stinging insect triggered reactions

One study found that 6.5% of beekeepers had a systemic reaction to bee sting in the past 12 months; 9/494 (2%) of these reactions resulted in anaphylaxis (27). The risk of systemic reactions increased when atopic disease was present: seasonal allergic rhinitis (OR 4.4, 95% CI 1.2 to 11.5), perennial rhinitis (OR 4.6, 95% CI 1.2 to 18.2), food allergy (OR 7.0, 95% 2.0 to 25.0), physician-diagnosed asthma (OR 8.0, 95% CI 2.5 to 25.6), and any atopic disease (OR 10.9, 95% CI 3.5 to 33.8).

### Latex triggered reactions

Focusing on pregnant women undergoing surgery in hospital, 2/588 (0.34%) experienced anaphylaxis due to latex allergy (29).

### Prognosis

Case fatality rates were noted in three studies at 0.000002% (52), 0.00009% (56), and 0.0001% (31).

### Studies in progress

We are aware of one study in progress which is investigating the epidemiology and healthcare utilization in children and adults with anaphylaxis in Denmark; this is expected to report in 2014.
**DISCUSSION**

**Summary of main findings**

The population-based incidence of anaphylaxis in Europe is estimated at 1.5 to 7.9 per 100000 person-years (57). There is some evidence that the incidence of anaphylaxis may be increasing but this may be due to changing clinical definitions or thresholds for presentation or admission. Studies would suggest that approximately 0.3% (95% CI 0.1 to 0.5) of the European population have experienced anaphylaxis at some point in their lives. These figures vary by age, geographical regions and exposure. They also depend on the source of data, for example historical medical records, national databases and data collected by general practitioners or specialists, and the definitions used (68). It was beyond the scope of this review to ascertain these factors. This review has also found that foods, drugs/therapeutic agents, stinging insects and latex are the most common triggers of anaphylaxis. Overall, the case fatality ratio from anaphylaxis was low, estimated at under 0.0001%.

**Strengths and limitations**

This is, as far as we are aware, the first systematic review of the epidemiology of anaphylaxis in European populations. Key strengths of this work include searches of a range of relevant databases, independent critical appraisal of studies, and, where appropriate, quantitative synthesis of data.

Our systematic review does not include studies prior to 2000 and is limited to Europe; this review may therefore not be generalisable to non-European settings. For example, it has excluded a recent epidemiological investigation from Turkey consisting of 114 patients hospitalised due to anaphylaxis over a one-year period giving a lifetime prevalence of 1.95 per 100000 person-years (95% CI 1.30 to 3.77) (69). The varying estimates of epidemiological frequency are likely to be due to varying study designs, approaches and definitions used by the authors. It was beyond the scope of this review to ascertain these factors. This review has also found that foods, drugs/therapeutic agents, stinging insects and latex are the most common triggers of anaphylaxis. Overall, the case fatality ratio from anaphylaxis was low, estimated at under 0.0001%.

**Interpreting findings in the context of the wider literature**

A review by a Working Group of the American College of Allergy, Asthma and Immunology summarised the findings from some principal studies published in English. Most of these were outside the time period of interest and included a number of non-European studies. This Working Group concluded that the overall incidence of anaphylaxis was between 30-60 cases per 100000 person-years and 950 cases per 100000 person-years, with a lifetime prevalence 0.05-2.0%. Even the higher figure could be an underestimate due to under-diagnosis and under-reporting (6). There may also be factors associated with poor diagnosis by non-specialists in allergy (70). Our pooled estimates are somewhat lower, although the range is very wide, perhaps reflecting differences in diagnostic criteria for anaphylaxis between Europe and North America.

**Implications for research, policy and practice**

The occurrence of anaphylaxis can have a profound effect on the quality of life of the sufferer and their family (71). The risk of recurrence may be high and some attacks prove fatal. Successfully identifying those at greatest risk of an initial attack, and a recurrence, could reduce morbidity, but this has proved difficult in practice using demographic and clinical markers. Genetic factors may have the potential to help fill this gap by identifying those at particularly high risk of severe reactions.

Secondary analyses of routine sources of data have proved helpful in describing the epidemiology of anaphylaxis, although the estimates generated would be considered more reliable if the data could be validated and linked across primary and secondary care sectors (72). Such validation work needs to be prioritised. Vigilance is needed as new drugs or foods are introduced. National reporting systems of adverse drug reactions or adverse reactions to foods associated with anaphylaxis may need reinforcing, perhaps through the use of prompts during patient consultations (73).
Conclusions
Improved data capture in and across routine health databases is required if we are to obtain more accurate estimates of the burden of anaphylaxis. This may be obtained through agreement on an acceptable definition of anaphylaxis (73) use of standard coding conventions (e.g. ICD-10, SNOMED-CT). At present, the best epidemiological estimates appear to come from north-west Europe, but more information is needed from southern and eastern Europe.

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AS, AM and GR conceived this review. It was undertaken by SSP with the support of SJ and DdS. SSP and AS led the drafting of the manuscript and all authors critically commented on drafts of the manuscript.

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4.2

MANAGEMENT OF ANAPHYLAXIS

SYSTEMATIC REVIEW

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**Background**: Anaphylaxis is an acute, potentially fatal, multi-organ system, allergic reaction. This systematic review aimed to assess the effectiveness of (1) interventions for the acute management of anaphylaxis and (2) pharmacological and non-pharmacological approaches for the long-term management of anaphylaxis.

**Methods**: Seven databases were searched for systematic reviews, randomized controlled trials, quasi-randomized controlled trials, controlled clinical trials, controlled before-after studies, and interrupted time series and–only in relation to adrenaline–case-series investigating the effectiveness of interventions in managing anaphylaxis.

**Results**: Fifty-five studies satisfied the inclusion criteria. We found no robust studies investigating the effectiveness of adrenaline (epinephrine), H1-antihistamines, systemic glucocorticosteroids or methylxanthines to manage anaphylaxis. There was evidence regarding the optimum route, site and dose of administration of adrenaline from trials studying people with a history of anaphylaxis. This suggested that administration of intramuscular adrenaline into the middle of vastus lateralis muscle is the optimum treatment. Furthermore, fatality register studies have suggested that a failure or delay in administration of adrenaline may increase the risk of death. The main long-term management interventions studied were anaphylaxis management plans and allergen-specific immunotherapy. Management plans may reduce the risk of further reactions, but these studies were at high risk of bias. Venom immunotherapy may reduce the incidence of systemic reactions in those with a history of venom-triggered anaphylaxis.

**Conclusions**: There is at present little in the way of robust evidence to guide decisions on the acute or long-term management of anaphylaxis. Given the risk of death and the considerable morbidity associated with anaphylaxis, these evidence gaps need to be filled.

**BACKGROUND**

Anaphylaxis can be defined as a “severe, life-threatening generalised or systemic hypersensitivity reaction” (1, 2). Several working definitions of anaphylaxis have been formulated to aid clinical diagnosis and management (1-4). The most well-known of these is the consensus clinical definition proposed by Sampson et al., which involved representatives of a number of international allergy organisations, including the European Academy of Allergy and Clinical Immunology (EAACI) (1).

Care of patients with anaphylaxis involves consideration of both the acute, emergency treatment of reactions and long-term care, which aims to reduce the risk of further reactions and improve outcomes if, despite these measures, a further reaction ensues (1). It remains very difficult to predict the severity of a reaction and, in fatal episodes, death may occur within minutes of an anaphylactic reaction, these observations underscoring the importance of effective, emergency management.

This systematic review is one of seven inter-linked evidence syntheses that were undertaken in order to provide a state-of-the-art synopsis of the current evidence-base in relation to epidemiology, prevention, diagnosis and clinical management, and impact on quality of life. There were used to inform clinical recommendations for the *EAACI Guidelines for Food Allergy and Anaphylaxis*.

**AIMS**

The aims of this systematic review were to assess the effectiveness of (1) interventions for the acute management of anaphylaxis and (2) pharmacological and non-pharmacological approaches for the long-term management of anaphylaxis.

**METHODS**

Details of the methodology for the identification, selection, and inclusion of the studies have been previously reported (9,10). In summary, our inclusion criteria were systematic reviews with or without meta-analyses, randomized controlled trials (RCTs), quasi-RCTs, controlled clinical trials (CCTs), controlled before-after (CBA) designs, interrupted time series (ITS) studies, and case-series, with a minimum of 10 patients, for studies investigating the use of adrenaline (Figure 1).

Standard methods for performing systematic reviews were used. A descriptive summary with data tables was produced to summarize the literature. Quality assessments of studies were undertaken using appropriate tools (see online supplement). We preferentially extracted data on risk ratios and mean differences. Because data were not suitable for meta-analysis (11), a narrative synthesis of the data was undertaken.

Further details can be found in the online supplement.

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**Figure 1** Conceptualization of systematic review of interventions for the acute and long-term management of anaphylaxis
RESULTS

The searches identified a total of 8929 potentially eligible studies, of which 55 satisfied our eligibility criteria and were therefore included in this review (Figure 2). The key characteristics and main findings of all included studies are detailed in online Table E1 and the quality assessment of these studies is summarized in Tables E2 (systematic reviews) and E3 (primary studies). The main findings are further discussed below.

ACUTE MANAGEMENT OF ANAPHYLAXIS

Adrenaline

We identified 14 studies: four systematic reviews (12-15) (including one update), four RCTs (16-19), two case-series (20, 21) and five fatality register-based reports (22-26) (including two updates) on the effectiveness of adrenaline.

Effectiveness and timing

Three well conducted systematic reviews (19-21) that looked at the use of adrenaline for the treatment of anaphylaxis and adrenaline auto-injectors found no RCTs or quasi-RCTs. Weaker evidence from a case series of 27 patients receiving emergency pre-hospital treatment found that prompt use of adrenaline may reduce the risk of fatality (26). The second case series found that a fifth of children experiencing anaphylaxis needed more than one dose of adrenaline; healthcare professionals administered this second dose in 94% of cases. The five fatality register-based reports (22-26) provided important insights into the difficulties of predicting the severity of subsequent reactions,
risk factors for fatality, co-existing asthma and the under-issuing, poor carriage, under-use, delayed use and incorrect use of adrenaline auto-injectors. These reports revealed that fatalities can occur, even if adrenaline is used correctly.

Site and route of delivery
Two RCTs (22, 24) found that, in both children and adults, maximal plasma concentration occurs quicker with the intra-muscular than subcutaneous route. The latter trial in adults also concluded that the optimum site of injection was the vastus lateralis muscle. A systematic review of poor quality found that the use of subcutaneous adrenaline was not contraindicated in patients older than 35 years without a history of coronary artery disease (17).

Dose in children
One RCT compared the effectiveness of the previous designs of the Epipen Junior and Epipen in children weighing 15-30 kgs. The authors concluded that children should be prescribed the 0.3mg Epipen from 30kgs (17).

Glucocorticosteroids
Two systematic reviews investigating the use of glucocorticosteroids in the acute management of anaphylaxis (27, 28) failed to identify any RCTs or quasi-RCTs and so were unable to make any recommendations.

Antihistamines
Two systematic reviews investigating the use of H1-antihistamines in the acute management of anaphylaxis (29, 30) identified no suitable RCTs or quasi-RCTs. Two RCTs that investigated the use of H1- and H2-antihistamines in acute allergic reactions (only a small proportion had anaphylaxis) (31, 32) revealed that the combination of H1- and H2-antihistamines was superior to H1-antihistamines alone in treating urticaria, but not angioedema; the second showed that pruritus was better controlled by H1-antihistamines than H2-antihistamines, and that combined treatment offered no advantage.

Methylxanthines
We found one systematic review investigating the effectiveness of methylxanthines in the acute management of anaphylaxis; this found no trials in humans (33).

LONG-TERM MANAGEMENT OF ANAPHYLAXIS

Anaphylaxis management plans
We identified two systematic reviews investigating anaphylaxis management plans (34, 35). The first found no evidence from RCTs or quasi-RCTs investigating the clinical effectiveness of anaphylaxis management plans for the prevention of recurrences or improvement in outcomes from anaphylaxis. The second systematic review had a wider focus including qualitative, epidemiological and experimental studies undertaken with or without a control group. This demonstrated that there were no universally accepted anaphylaxis management plans. It however identified four studies, which suggested that anaphylaxis management plans may substantially reduce the risk of future, severe reactions.

Venom immunotherapy (VIT)
We found three systematic reviews and meta-analyses (36-38) and one further systematic review without a meta-analysis investigating the effectiveness of VIT. These four systematic reviews included a total of 23 unique studies of varying quality. Twelve of these studied patients with a history of anaphylaxis using eligible study designs and have therefore also individually been assessed (see Tables E1 and E3) (40-51).

The high-quality systematic review by Boyle et al., identified six RCTs and 1 quasi-RCT (392 participants) (36). Five studies involved subcutaneous immunotherapy and one sublingual immunotherapy. Patients treated with VIT had less systemic allergic reactions (RR=0.10, 95% CI 0.03 to 0.28) and better quality of life (mean difference=1.21 points on a 7-point scale (95% CI 0.75 to 1.67)). Subcutaneous VIT treated patients had more systemic adverse reactions (RR=8.16, 95% CI 1.53 to 43.46). One systematic review of low quality showed that VIT was effective in reducing the risk of further systemic reactions (49).

The systematic review by Hockenhull et al. (39) investigated the clinical- and cost-effectiveness of a specific VIT subcutaneous preparation (Pharmalgen), and included nine trials (four RCTs and five quasi-RCTs), all judged to be of poor quality. They modelled cost-effectiveness showing a cost of £8-20 (€10-25)
million/life year gained, assuming a base-case scenario of no improvement in quality of life. A sensitivity analysis showed that VIT was more cost-effective in those at high risk of further stings or if improvements in quality of life and anxiety associated with VIT were included in the model.

**Educational interventions**
A quasi-experimental trial evaluated whether an educational intervention could improve compliance with carrying an in-date adrenaline auto-injector in high school children with food allergy (52). The intervention failed to demonstrate any significant difference in carriage rates in the intervention and control groups.

**Psychological interventions**
One systematic review of low quality investigated the management of anxiety related to children with a history of anaphylaxis (53). It concluded that anaphylaxis can place a substantial psychological burden on children, adolescents and carers, and that dealing with this anxiety may improve outcomes.

**Prophylactic interventions**
Interventions have been studied to prevent anaphylaxis. A major limiting factor with these studies is the fact that the groups studied were not known to be at high risk of anaphylaxis.

*Adrenaline admixture with snakebite anti-venom*
A systematic review and meta-analysis demonstrated that adrenaline premedication reduces adverse reactions when administering snakebite anti-venom (54) (RR=0.32, 95% CI 0.18 to 0.58). A subsequent factorial designed RCT investigated the use of adrenaline, antihistamines and glucocorticosteroids given alone or in combination (55). This also found adrenaline, but not other interventions, to be effective in reducing the risk of anaphylaxis.

*Pharmacological interventions for the prevention of anaphylaxis to iodinated contrast media*
One systematic review of nine trials involving 10011 unselected patients failed to demonstrate that premedication with glucocorticosteroids, H1-antihistamines or a combination of H1- and H2-antihistamines prevented anaphylaxis triggered by iodinated contrast media (56).

**Discussion**
This comprehensive review of the international literature has found little robust evidence for the acute or long-term management of anaphylaxis. The only trial evidence uncovered for the emergency management of anaphylaxis was in relation to adrenaline, but these trials have been undertaken in patients who were at the time not experiencing anaphylaxis (22-25). Taken together with the methodologically lower quality evidence from case-series and fatality registers, there is some evidence to support the use of adrenaline for the emergency management of anaphylaxis. The evidence points to the importance of injecting this by the intramuscular route into the antero-lateral aspect of the thigh. In relation to longer-term management considerations, anaphylaxis management plans may be effective in reducing the risk of recurrence. VIT reduces the severity of reactions to subsequent stings and improves quality of life and concerns around cost-effectiveness remain.

**Acute management of anaphylaxis**
Case fatality register studies have demonstrated that deaths can occur within minutes of the onset of a reaction and have highlighted how difficult it is to predict the severity of reactions (12). It is therefore consistently advocated by guidelines that all reactions are promptly managed by initiating a range of pharmacological and non-pharmacological interventions. This review failed to identify any high-quality studies investigating the role of non-pharmacological interventions such as the role of cardiopulmonary resuscitation and posture. In contrast, we found some evidence investigating the role of adrenaline – the main drug treatment advocated in guidelines. This evidence was derived from case series, fatality registers and a limited number of trials in people not experiencing anaphylactic reactions. Overall, this body of evidence was weak, but pointed to the importance of the early administration of adrenaline, in an appropriate dose, administered by the intramuscular route into the anterolateral aspect of the thigh. Given the considerable ethical and logistical challenges in undertaking trials of parenteral adrenaline in patients experiencing anaphylaxis, it is unlikely that stronger evidence will be forthcoming.

We found no evidence from primary studies for other potential treatments, such as fluid replacement, oxygen, glucocorticosteroids, antihistamines, methylxanthines
and bronchodilators, and it is therefore not possible to offer any recommendations for the use of these treatments.

**Long-term management of anaphylaxis**

The long-term management of anaphylaxis centres on the need to identify triggers and co-factors, providing advice on how to minimise further reactions, and equipping individuals with the skills and equipment needed to manage further reactions (57). Consideration also needs to be given to ameliorate any psychological consequences of a diagnosis of anaphylaxis. Researchers have therefore thus far focused attention on the role of anaphylaxis management plans, immune-modulatory interventions, and a variety of educational and psychological interventions.

The formal experimental evidence in support of anaphylaxis management plans is limited. Studies that have, however, used before-after designs and which therefore did not satisfy our inclusion criteria have found that these may result in substantial reductions in the risks of further reactions (58, 59). Given the high risk of confounding with such study designs, this evidence must be interpreted with caution.

The single educational study included failed to show a positive effect on carriage of in-date adrenaline auto-injectors by high school children with previous anaphylaxis. A study with a before-after design found that the input of a multi-disciplinary allergy clinic was effective in improving parents’ knowledge of food allergy and in reducing subsequent reactions (60). This evidence is encouraging, but due to the high inherent risk of bias associated with such a design these findings need to be treated with caution until more evidence from studies employing more robust study designs are forthcoming. The systematic review on psychological interventions for children with a history of anaphylaxis and their parents/carers was difficult to interpret because of its poor quality and reporting. Whilst clearly demonstrating that a number of studies have found that a diagnosis of anaphylaxis can be associated with anxiety and impaired quality of life, there was very little in the way of primary evidence demonstrating that intervening could improve outcomes in such individuals/families.

Immuno-modulatory approaches are of considerable interest as these have the potential to modify the disease course and may possibly prove curative. We found a modest body of evidence in relation to VIT in relation to the management of those with stinging-insect anaphylaxis, although much of this was judged to be at high risk of bias. This body of evidence did however consistently demonstrate that VIT can significantly reduce the severity of subsequent systemic reactions to insect stings, but given the infrequency of further stings and the low number of fatalities, it was not possible to assess whether VIT reduced the risk of fatal reactions to insect stings. There were no formal cost-effectiveness studies identified, the only potentially relevant evidence emerging from modelling studies in relation to a specific product: this found that VIT is most likely to be cost-effective in populations at high risk of further exposure (e.g. bee keepers, their family members and those who live near bee farms) or if likely benefits to quality of life are accounted for. VIT is a treatment which has been shown to reduce subsequent reactions and although the treatment may give rise to adverse effects it is a treatment patients prefer over the long-term carriage of an adrenaline auto-injector. In state-funded health services, however, the cost implications of such an intervention may prevent widespread availability limiting its use to high-risk patients only where its cost-effectiveness profile is likely to be much more favorable.

We found no eligible studies investigating the role of desensitization therapy in the management of those with anaphylaxis to drugs or latex. Studies investigating the effectiveness of oral and sublingual immunotherapy have mainly been undertaken in those without a history of anaphylaxis to foods; these studies are therefore reviewed in the companion systematic review on the management of food allergy.

Prophylactic approaches can also potentially play a role in those with a history of anaphylaxis. The evidence we uncovered did not however directly focus on this population. Rather, the approaches studied have been used in the general population and have found that: prophylactic use of adrenaline can substantially reduce the risk of anaphylaxis associated with anti-snake venom and that adding antihistamines or glucocorticosteroids conferred no additional advantage; and that antihistamines and glucocorticosteroids were of questionable value in preventing anaphylaxis associated with iodinated contrast media based diagnostic investigations in unselected populations.
Implications for future research

This review has underscored the dearth of high quality research to guide everyday clinical decision making. There is then a pressing need to develop the evidence-base for both the acute and long-term management of this potentially life-threatening disorder. In relation to acute management, it is widely accepted that it would be unethical to undertake studies investigating the effectiveness of adrenaline when compared with placebo, but trials could potentially be undertaken investigating the optimum dose, site, route and timing of administration of adrenaline. Other important questions that need to be addressed include establishing the role of H1- and H2-antihistamines and glucocorticosteroids and these could also potentially be investigated using formal experimental designs. Similarly, there are a range of interventions delivered with the aim of improving longer-term outcomes – for example, provision of adrenaline auto-injectors, anaphylaxis management plans, immunotherapy – and these can all potentially also be studied using formal trial designs. Ideally, these studies should investigate the impact of interventions on the outcomes that have been carefully described in recent Cochrane and other systematic reviews (12, 14, 28, 29, 35). A fuller discussion of the research agenda will be made available in the forthcoming EAACI Anaphylaxis Guidelines (Chapter 4.3).

Conclusions

There is at present little in the way of robust evidence to guide decisions on the acute or long-term management of anaphylaxis. Key recommendations from this review have been summarized in Box 1. Given the risk of death and the considerable morbidity associated with anaphylaxis these evidence gaps need to be filled wherever possible (61). These gaps include the need for educational interventions for patients, carers and healthcare professionals, lack of data on the pharmacodynamics of adrenaline and the ideal dosage in children and to some extent adults, and a lack of effective study designs on the benefits of educational plans (62).

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Contributorship

AS, AM and GR conceived this review. It was undertaken by SD with the support of SSP, GR and AS. SD, AS and GR led the drafting of the manuscript and all authors critically commented on drafts of the manuscript.

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Conflicts of interest

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Managing anaphylaxis


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Anaphylaxis is a clinical emergency and all healthcare professionals should be familiar with its recognition and acute and ongoing management. These guidelines have been prepared by the European Academy of Allergy and Clinical Immunology (EAACI) Taskforce on Anaphylaxis. They aim to provide evidence-based recommendations for the recognition, risk factor assessment and the management of patients who are at risk of, are experiencing, or have experienced anaphylaxis. While the primary audience is allergists, these guidelines are also relevant to all other healthcare professionals. The development of these guidelines has been underpinned by two systematic reviews of the literature, on the epidemiology and clinical management of anaphylaxis. Anaphylaxis is a potentially life-threatening condition whose clinical diagnosis is based on recognition of a constellation of presenting features. First-line treatment for anaphylaxis is intramuscular adrenaline. Useful second-line interventions may include removing the trigger where possible, calling for help, correct positioning of the patient, high flow oxygen, intravenous fluids, inhaled short-acting bronchodilators and nebulized adrenaline. Discharge arrangements should involve an assessment of the risk of further reactions, a management plan with an anaphylaxis emergency action plan and, where appropriate, prescribing an adrenaline auto-injector. If an adrenaline auto-injector is prescribed, education on when and how to use the device should be provided. Specialist follow-up is essential to investigate possible triggers, to perform a comprehensive risk assessment and prevent future episodes by developing personalized risk reduction strategies including, where possible, commencing allergen immunotherapy. Training for the patient and all caregivers is essential. There are still many gaps in the evidence base for anaphylaxis.

BACKGROUND

Anaphylaxis is a clinical emergency and all healthcare professionals should be familiar with its management. These guidelines have been prepared by the European Academy of Allergy and Clinical Immunology’s (EAACI) Taskforce on Anaphylaxis and are part of the EAACI Guidelines for Food Allergy and Anaphylaxis. The guidelines aim to provide evidence-based recommendations for the recognition, risk assessment and management of patients who have experienced, are experiencing or are at risk of experiencing anaphylaxis. The primary audience is allergists but they are also likely to be of relevance to all other healthcare professionals (e.g. doctors, nurses and paramedics) in emergency departments (ED), hospital and primary care. Development of the guidelines have been informed by two systematic reviews of the epidemiology and clinical management of anaphylaxis (1, 2) with weaker forms of evidence being used where there were insufficient data or where high level evidence is practically or ethically unobtainable. These guidelines build on the previous EAACI Position Paper on Anaphylaxis in Childhood (3) and are complementary to other current anaphylaxis guidelines (4-6). Distinctive features include a European focus and the placing of particular emphasis on the practical issues associated with long-term management.

Anaphylaxis is defined as a “severe, life-threatening systemic hypersensitivity reaction” (7) (Box 1). This is characterized by being rapid in onset with life-threatening airway, breathing or circulatory problems; it is usually, but not always, associated with skin and mucosal changes (5). These guidelines focus mainly on allergic anaphylaxis involving specific-immunoglobulin-E (IgE) but are also relevant to anaphylaxis involving other mechanisms.

METHODS

These Guidelines were produced using the Appraisal of Guidelines for Research & Evaluation (AGREE II) approach (8, 9), a structured approach to guideline production. This is designed to ensure appropriate representation of the full range of stakeholders, a careful search for and critical appraisal of the relevant literature, a systematic approach to the formulation and presentation of recommendations, and steps to ensure that the risk of bias is minimized at each step of the process. The process began in January 2012, ensuing over 18 months, with in detail discussion of the frame of guidelines for clinical practice, the main aims of the guidelines, the target conditions, agreeing the intended end-user for the recommendations, agreeing the intended end-user group, and ensuring adequate professional and lay representation in the guidelines development process. The process involved:

Clarifying the scope and purpose of the guidelines

The scope of these EAACI guidelines is multifaceted providing statements that assist clinicians

Box 1 Key terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaphylaxis</td>
<td>Severe, potentially life-threatening systemic hypersensitivity reaction (6, 7). This is characterized by being rapid in onset with life-threatening airway, breathing or circulatory problems, and is usually, although not always, associated with skin and mucosal changes.</td>
</tr>
<tr>
<td>Adrenaline (epinephrine)</td>
<td>A drug with combined α- and β-agonist actions which result in (i) peripheral vasoconstriction thereby reversing hypotension and mucosal edema, (ii) increased rate and force of cardiac contractions thereby reversing hypotension, and (iii) reversal of bronchoconstriction and reduction in release of inflammatory mediators.</td>
</tr>
<tr>
<td>Adrenaline auto-injector</td>
<td>Device designed to be used by a non-medical person to give a pre-defined dose of intramuscular adrenaline.</td>
</tr>
<tr>
<td>Co-factors</td>
<td>Patient-related or external circumstances that are associated with more severe allergic reactions. They are also known as augmentation factors.</td>
</tr>
<tr>
<td>Management plans</td>
<td>Lay summary of the clinical plan that patients should follow. It will have an emergency action plan with likely presenting symptoms and how to respond to each. It should also provide additional information such as avoidance advice if applicable and contact details for further advice from allergy clinic and patient support groups.</td>
</tr>
</tbody>
</table>
in the management of anaphylaxis in daily practice, harmonizing the approach to this clinical emergency among stakeholders across Europe and advocating for further research.

**Ensuring appropriate stakeholder involvement**

Participants in the Anaphylaxis Taskforce represented a range of 14 European countries, and disciplinary and clinical backgrounds, for example emergency physicians (A B Bellou), primary care (A Sheikh), psychology (A DunnGalvin), patient groups (F Timmermans, L Harada) and dietitians (BJ Vlieg–Boerstra).

**Systematic reviews of the evidence**

The initial full range of questions that were considered important were rationalized through several rounds of iteration to agree to three key questions that were then pursued through two formal systematic reviews of the evidence (1, 2, 10, 11) (see Box 2) (see Chapters 4.1, 4.2).

**Formulating recommendations**

We graded the strength and consistency of key findings from these systematic reviews to formulate evidence-linked recommendations for care (12) (Box 3). This involved formulating clear recommendations and making clear the strength of evidence underpinning each recommendation. Experts identified the resource implications of implementing the recommendations, barriers and facilitators to the implementation of each recommendation, advice on approaches to implementing the recommendations and suggested audit criteria that can help with assessing organizational compliance with each recommendation.

**Peer review and public comment**

A draft of these guidelines was externally peer-reviewed by invited experts from a range of organizations, countries and professional backgrounds. Additionally the draft guidelines were made available on the EAACI website for a 3-week period in June 2013 to allow all stakeholders to comment. All feedback was considered by the Anaphylaxis Taskforce and, where appropriate, final revisions were made in light of the feedback received. We will be pleased to continue to receive feedback on these guidelines, which should be addressed to the first author.

**Identification of evidence gaps**

The process of developing these guidelines has identified a number of evidence gaps and we plan in future to formally prioritize these. We plan to draft outline research briefs that funders can use to commission research on these questions.

**Box 2** Key questions addressed in the two supporting systematic reviews (1, 2)

- What is the epidemiology (i.e. frequency, risk factors and outcomes) of anaphylaxis and how do these vary by time, place and person?
- What is the effectiveness of interventions for the acute management of anaphylaxis?
- What is the effectiveness of interventions for the long-term management of those at high risk of further episodes of anaphylaxis?

**Box 3** Assigning levels of evidence and recommendations (12)

<table>
<thead>
<tr>
<th>LEVEL OF EVIDENCE</th>
<th>GRADES OF RECOMMENDATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>Consistent level I studies</td>
</tr>
<tr>
<td>Level II</td>
<td>Consistent level II or III studies or extrapolations from level I studies</td>
</tr>
<tr>
<td>Level III</td>
<td>Level IV studies or extrapolations from level II or III studies</td>
</tr>
<tr>
<td>Level IV</td>
<td>Level V evidence or troublingly inconsistent or inconclusive studies at any level</td>
</tr>
<tr>
<td>Level V</td>
<td>Consistent level II or III studies or extrapolations from level I studies</td>
</tr>
</tbody>
</table>

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**GRADES OF RECOMMENDATION**

- Grade A: Consistent level I studies
- Grade B: Consistent level II or III studies or extrapolations from level I studies
- Grade C: Level IV studies or extrapolations from level II or III studies
- Grade D: Level V evidence or troublingly inconsistent or inconclusive studies at any level
Editorial independence and managing conflict of interests
The production of these guidelines was funded and supported by EAACI. The funder did not have any influence on the guidelines production process, its contents or on the decision to publish. Taskforce members’ conflicts of interest were taken into account by the Taskforce chair as recommendations were formulated.

Updating the Guidelines
We plan to update these guidelines in 2017 unless there are important advances before then.

Epidemiology
A detailed description of the epidemiology of anaphylaxis can be found in the underpinning systematic review referred to above (1) (Chapter 4.1). The exact incidence and prevalence of anaphylaxis in Europe is challenging to establish due to a number of factors. The current definition of anaphylaxis is complex and difficult to use in epidemiological studies (13). Additionally, the World Health Organization’s International Classification of Diseases codes (ICD-9 and current ICD-10) focus on anaphylactic shock and do not cover the full range of triggers meaning that not all allergy cases are likely to be captured in routine data systems. ICD-11 is in development but still seems to miss major triggers (14). Additionally, anaphylaxis has an acute and unexpected onset, may vary in severity, and may resolve spontaneously (15). For all these reasons under-diagnosis and under-reporting are likely to be common and as a result epidemiological measures are likely to underestimate the true disease burden.

The results of 10 European studies suggest an incidence of 1.5 to 7.9 per 100000 person-years (1) with studies from the UK showing an increase in admissions with anaphylaxis over the last two decades (1). Based on three European population-based studies, prevalence is estimated at 0.3% (95% CI, 0.1-0.5) (1). Overall, the case fatality rate for anaphylaxis is low, below 0.001% (1).

Key triggers include food, drugs and stinging insects; in up to 20% the elicitor is not identified. Their relative importance varies with age and geography studied. For ED presentations, drugs and foods are the most common elicitors of anaphylaxis, with age-related differences (1, 16). Foods are the most frequent cause of anaphylaxis in children, with pollen allergy and asthma being important risk factors (1). Drug and Hymenoptera venom triggered anaphylaxis are more common in adults than in children. Compared to males, adult females have a higher frequency of anaphylaxis (1) in general, and specifically to plant foods and non-steroidal anti-inflammatory drugs (NSAID) (1). Drugs are the most frequent cause of anaphylaxis in hospitalized patients (1). For anaphylaxis during anesthesia, neuromuscular blocking agents are the most frequent triggers in adult patients in most countries, with a higher incidence in females (1).

Clinical presentation and diagnosis
The clinical manifestations of anaphylaxis depend on the organ systems involved. Widely accepted criteria to help clinicians identify likely anaphylaxis (17, 18) (Box 4) emphasize the rapid onset of its multiple symptoms and signs. These criteria significantly improve the identification of anaphylaxis (19) and demonstrate excellent sensitivity (96.7%) and good specificity (82.4%) for the diagnosis of anaphylaxis in a retrospective ED study (20). Symptoms and signs of anaphylaxis usually occur within two hours of exposure to the allergen (21), usually within 30 minutes for food allergy and even faster with parenteral medication or insect stings. In a large case series of fatal anaphylaxis, the median time from symptoms to arrest has been reported as 30, 15 and 5 minutes for food, insect venom and parenteral medication respectively (22).

Among the symptoms of anaphylaxis, cutaneous manifestations occur in most cases (23, 24). In a recent study describing a cohort of 2012 pediatric and adult patients with anaphylaxis, the skin was the most frequently affected organ (84%), followed by cardiovascular symptoms (72%) and respiratory symptoms (68%) (25). Anaphylaxis however can develop in the absence of cutaneous manifestations. Respiratory or cardiovascular symptoms or signs are the potentially life-threatening features of anaphylaxis (26). Respiratory symptoms occur more frequently in children and cardiovascular symptoms predominate in adults (25-31). Nausea and vomiting may also be associated with anaphylaxis (22) (Figure 1).
Biphasic anaphylactic reactions have been reported to develop in up to 20% of reactions (24, 32-34) although the evidence for this is of low quality. They usually occur within 4-12 hours of the first symptoms or signs and may be more severe. A delay in giving adrenaline (epinephrine), insufficient adrenaline or failure to administer a glucocorticosteroid may increase the risk of biphasic reactions (33-37).

Anaphylaxis is a clinical diagnosis that builds on the criteria shown in Box 4. Retrospectively the diagnosis may be supported if serum tryptase is elevated within a few hours after the reaction when compared with the patient’s baseline levels; levels are often normal especially in food-triggered reactions in children (38). Evidence of IgE sensitization on skin prick (39) or in vitro testing may also aid the diagnosis; provocation testing, ideally with any potential co-factors (40), may be required if diagnostic doubt remains (26). Children may outgrow their food allergy, even if severe (41).

The differential diagnosis of anaphylaxis includes medical diseases, which affect the organ systems most frequently involved in anaphylaxis (Box 5).

Factors increasing the risk of severe allergic reactions
Risk factors for anaphylaxis include individual patient related factors and circumstances (25, 26, 42-46) (Box 6). We do not have precise data on the magnitude of risk associated with each.

Concomitant diseases
Co-existing asthma is a risk factor for anaphylaxis and fatal anaphylaxis, especially if severe and uncontrolled (47, 48). Mast cell disorders, and probably underlying cardiovascular disease, are also associated with an increased risk of severe or fatal anaphylaxis (24, 49, 50).

Specific allergens
Patients with peanut and tree nut allergy are at increased risk for a severe reaction (51). In patients with insect venom allergy, increased severity has been reported for older age, pre-existing cardiovascular disease, mast cell disorder, including mastocytosis and mast cell activation syndrome (52, 53), elevated baseline serum tryptase concentrations, concomitant treatment with a beta-adrenergic-blocker and/or angiotensin converting enzyme (ACE) inhibitor and a previous severe reaction (54-57).

Co-factors
Co-factors increase the risk of an allergic reaction occurring or its severity. They have been described in nearly 20% of young patients in a prospective registry study (28) (Table 1) and include exercise, fever, acute infection, premenstrual status and emotional stress. NSAID and alcohol also seem to enhance some food allergic reactions (40). Exercise-induced anaphylaxis (EIA) and food-dependent, exercise-induced
anaphylaxis (FDEIA) are more often seen in adults than in children. The association with exercise is crucial for the onset of symptoms or signs (58-60). The range of triggering physical activities and intensities is broad. EIA is not fully reproducible so that same exercise may not always result in anaphylaxis in a given patient.

**Emergency management of anaphylaxis**

Patients with anaphylaxis require immediate assessment using an Airway, Breathing, Circulation, Disability and Exposure approach. Problems should be treated as they are found and a call put out for emergency services (Box 7). Deaths result from upper airway, lower respiratory and/or cardiovascular compromise so emergency management must focus on these manifestations. We recommend first-line treatment with intramuscular adrenaline before instituting other interventions as adrenaline is still underutilized in anaphylaxis (61) although it is potentially lifesaving. Cardiopulmonary resuscitation should be immediately instituted if cardiorespiratory arrest occurs. An overview is presented in Figure 2 and check list in Box 8.

**First-line intervention**

**Adrenaline**

Adrenaline must be administered to all patients experiencing anaphylaxis; it should also be administered to those with clinical features that are likely to evolve into anaphylaxis (22, 45, 46, 62-64) (C). In an effort to increase the use of adrenaline, these guidelines place adrenaline as the first intervention for anaphylaxis. Adrenaline exerts effects on (i) α-1 receptors causing peripheral vasoconstriction thereby reversing hypotension and mucosal edema, (ii) β-1 receptors by increasing both the rate and force of cardiac contractions thereby reversing hypotension and mucosal edema, and (iii) β-2 receptors reversing bronchoconstriction and reducing the release of inflammatory mediators (62).

---

### Symptoms

<table>
<thead>
<tr>
<th>CARDIO- VASCULAR</th>
<th>MULTIPLE SYSTEMS</th>
<th>RESPIRATORY ONLY</th>
<th>GI ONLY</th>
<th>SKIN ONLY</th>
<th>BEHAVIOUR</th>
</tr>
</thead>
</table>

---

**Figure 1** Symptoms associated with anaphylaxis

Adrenaline is effective for all symptoms
There are no absolute contra-indications to treatment with adrenaline in a patient experiencing anaphylaxis; benefits outweigh the risks in the elderly and patients with pre-existing cardiovascular disease (6). Adrenaline should be given by intramuscular injection into the mid-outer thigh (65, 66) (A). The safety profile of intramuscular adrenaline is excellent although patients may experience transient pallor, palpitations and headache. Intramuscular adrenaline (1 mg/ml) should be given at a dose of 0.01 ml/kg of body weight to a maximum total dose of 0.5 ml (3). When using adrenaline auto-injectors, patients weighing between 7.5-25 kg should receive a 0.15 mg dose with patients being a 0.3 mg dose at 25-30 kg (67). There are no data to inform us which patients should receive a 0.5 mg dose auto-injector, if this is available. The adrenaline dose can be repeated after at least a 5 minute interval (D).

Patients who require repeated intramuscular doses of adrenaline may benefit from an adrenaline infusion (64) (D). Adrenaline infusion must be given by those experienced in the use of vasopressors in their daily clinical practice, for example anesthetists, ED and critical care doctors. Intravenous adrenaline in patients with adequate circulation may cause life-threatening hypertension, myocardial ischemia, and arrhythmias. Patients who are given intravenous adrenaline should be monitored with continuous ECG, pulse oximetry and frequent non-invasive blood pressures.

The use of subcutaneous or inhaled adrenaline in the treatment of anaphylaxis is not recommended (68, 69). One caveat is stridor from laryngeal edema where nebulized adrenaline (2–5 ml, 1 mg/ml) can be used in addition to intramuscular adrenaline (3) (D).
### Box 7 Emergency management: recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRST-LINE INTERVENTION: ADRENALINE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adrenaline is potentially life-saving and must therefore promptly be administered as the first-line treatment for the emergency management of anaphylaxis.</td>
<td>IV</td>
<td>C</td>
<td>22, 45, 46, 63, 64</td>
</tr>
<tr>
<td>Earlier administration of adrenaline should be considered on an individual basis when an allergic reaction is likely to develop into anaphylaxis.</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
</tr>
<tr>
<td>Adrenaline should be administered by intramuscular injection into the mid-out outer thigh.</td>
<td>I</td>
<td>B</td>
<td>65, 66</td>
</tr>
<tr>
<td>In patients requiring repeat doses of adrenaline, these should be administered at least 5 minutes apart</td>
<td>V</td>
<td>D</td>
<td>66</td>
</tr>
<tr>
<td>With inadequate response to 2 or more doses of intramuscular adrenaline, adrenaline may be administered as an infusion by appropriately experienced intensive care, emergency department and critical care physicians, with appropriate cardiac monitoring.</td>
<td>IV</td>
<td>D</td>
<td>64</td>
</tr>
<tr>
<td><strong>SECOND-LINE INTERVENTIONS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trigger of the anaphylaxis episode should be removed.</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
</tr>
<tr>
<td>Help should be called promptly and simultaneously with patient’s assessment.</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
</tr>
<tr>
<td>Patients experiencing anaphylaxis should be positioned supine with elevated lower extremities if they have circulatory instability, sitting up if they have respiratory distress and in recovery position if unconscious.</td>
<td>V</td>
<td>D</td>
<td>45</td>
</tr>
<tr>
<td>High flow oxygen should be administered by face mask to all patients with anaphylaxis.</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
</tr>
<tr>
<td>Intravenous fluids (crystalloids) should be administered (boluses of 20 ml/ kg) in patients experiencing cardiovascular instability.</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
</tr>
<tr>
<td>Inhaled short-acting beta-2 agonists should additionally be given to relieve symptoms of bronchoconstriction.</td>
<td>V</td>
<td>D</td>
<td>22</td>
</tr>
<tr>
<td><strong>THIRD-LINE INTERVENTIONS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral H1 - (H2)-antihistamines may relieve cutaneous symptoms of anaphylaxis.</td>
<td>I</td>
<td>B</td>
<td>73, 74</td>
</tr>
<tr>
<td>Systemic glucocorticosteroids may be used as they may reduce the risk of late phase respiratory symptoms. High dose nebulized glucocorticoids may be beneficial for upper airway obstruction.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td><strong>MONITORING AND DISCHARGE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients who presented with respiratory compromise should be closely monitored for at least 6-8 hours and patients who presented with circulatory instability require close monitoring for 12-24 hours.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Before discharge, the risk of future reactions should be assessed and an adrenaline auto-injector should be prescribed to those at risk of recurrence.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Patients should be provided with a discharge advice sheet, including allergen avoidance measures (where possible) and instructions for the use of the adrenaline auto-injector. Specialist and food allergy specialist dietitian (in food anaphylaxis) follow-up should be organized. Contact information for patient support groups should also be provided.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
</tbody>
</table>
**Figure 2** Schematic illustration of the initial management of anaphylaxis
Second-line interventions

Removal of the trigger and call for help

The likely trigger of the anaphylaxis should be immediately removed, if possible (69) (D). Help should be called from the emergency medical services in the community or resuscitation team in hospital (69) (D).

Posture

Patients experiencing anaphylaxis should be kept still and positioned according to their presenting features: (i) with the most frequent presentation of respiratory distress, position sitting up (D); (ii) with circulatory instability, position lying on back with the lower extremities elevated to conserve the circulatory volume (45) (D); (iii) if pregnant, place semi-recumbent on the left side with lower extremities elevated (70) (D); and (iv) where unconscious, place in the recovery position (D). Patients should avoid sudden abrupt change to a more upright posture (D).

Oxygen

High flow oxygen should be administered by face mask to all patients with anaphylaxis (D).

Fluid support

Intravenous fluids should be administered to patients with cardiovascular instability (71), as adrenaline may not be effective without restoring the circulatory volume (D). Crystalloids are the fluid of choice and should be given in boluses of 20 ml/kg (D).

Inhaled short-acting beta-2-agonists

Inhaled short-acting beta-2 agonists can be additionally given to relieve symptoms of bronchoconstriction in patients with anaphylaxis (22) (D). Although intramuscular adrenaline is first-line treatment in the emergency setting, in controlled circumstances in hospital with clinical staff experienced in managing anaphylaxis (e.g. oral food challenge in an allergy clinic), mild wheeze may initially be treated with inhaled short-acting beta-2 agonists alone; intramuscular adrenaline should be given if there is no response within 5 minutes (D).

Third-line interventions

H1- and H2-antihistamines

Systemic antihistamines are commonly used in anaphylaxis but have only been demonstrated to relieve cutaneous symptoms in studies where only a minority of participants were experiencing anaphylaxis (72). The combination of systemic H1- and H2-antihistamines may confer additional benefits over-and-above systemic H1-antihistamines alone in relieving some cutaneous symptoms in those experiencing acute allergic reactions (73, 74). There are case reports that intravenous antihistamines may cause hypotension; this may be related to the speed of administration (75). Oral H1- (& H2)-antihistamines are therefore only recommended for the relief of cutaneous symptoms of anaphylaxis (B).

Glucocorticosteroids

Oral or intravenous glucocorticosteroids are commonly used in anaphylaxis and are thought to possibly prevent protracted anaphylaxis symptoms, particularly in patients with concomitant asthma, and also biphasic reactions; however, this has not been proven and they have a slow onset of action. Oral or parenteral glucocorticosteroids may be given once first- and second-line therapies have been administered (D). High doses of nebulized budesonide may be effective for airway oedema (D); this is therefore recommended for patients presenting with stridor.

Other potential treatments

Glucagon

Parenteral administration of glucagon may be useful in treating patients with anaphylaxis who are unresponsive to adrenaline, particularly in those taking beta-blockers (76) (D).

Monitoring and discharge arrangements

Patients who presented with respiratory compromise should be closely monitored for at least 6-8 hours
and patients who presented with hypotension require close monitoring for at least 12-24 hours (D). Before discharge, the risk of future reactions should be assessed and an adrenaline auto-injector prescribed to those at risk of recurrence (D). Patients should be provided with a discharge advice sheet, including allergen avoidance measures (where possible), instructions for when and how to use the adrenaline auto-injector; referral to an allergy specialist to investigate possible triggers, assess and, where possible, to intervene to minimize the risk of further reactions and ensure that patients and caregivers are optimally equipped and trained to manage any further reactions, and, if food is involved, referral to a specialist dietitian (D). Contact information for patient support groups should ideally be provided to signpost sources of further useful information.

Long-term management of anaphylaxis

The long-term management of patients who have experienced anaphylaxis starts with the confirmation of triggering allergens using validated in-vivo and/or in-vitro tests interpreted in the light of a detailed allergy history. Preventive strategies to avoid recurrence include allergen avoidance (3) and allergen immunotherapy where possible should be implemented. Finally, education should be provided covering self-treatment of anaphylaxis recurrence in the community, and management of relevant concomitant diseases (6) (Box 9). An allergy specialist dietitian can help identify food triggers and provide avoidance advice. Patients should be carefully instructed about hidden allergens, cross-reactions to other allergens and situations that constitute a special hazard such as eating out (see for further details, Chapter 1.5) (77) (Box 9). Most recommendations are based on expert opinion (Box 10).

Anaphylaxis management plans

Anaphylaxis management plans should cover avoidance advice, contact details for advice plus an anaphylaxis emergency action plan with likely presenting symptoms and how to respond to each. Studies have shown that after the inception of a management plan, accidental reactions are less common, at least in children with peanut or tree nut allergies (78, 79). A management plan used by a multi-disciplinary allergy clinic had a positive effect on parental knowledge of avoidance measures and emergency treatment of reactions in another study (80). Anaphylaxis management plans should be used from diagnosis to aid recognition and treatment of any further reactions and should be regularly updated (81, 82) (C) (Box 11).

Indications for adrenaline auto-injectors

There are six absolute indications for a prescription of an adrenaline auto-injector (Box 12): (i) previous
Box 10 Long-term management: recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAPHYLAXIS MANAGEMENT PLAN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An anaphylaxis management plan should be used from the time of diagnosis to prevent future reactions, and aid recognition and treatment of any further reactions.</td>
<td>III</td>
<td>C</td>
<td>79, 80</td>
</tr>
<tr>
<td>VENOM IMMUNOTHERAPY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcutaneous venom immunotherapy is recommended in venom allergic patients with a previous episode of anaphylaxis and adults with systemic cutaneous reactions.</td>
<td>I</td>
<td>A</td>
<td>56, 90, 91, 92, 93</td>
</tr>
<tr>
<td>TRAINING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training in the recognition and management of anaphylaxis should be offered to all patients and caregivers of children at risk of anaphylaxis ideally from the time of diagnosis.</td>
<td>V</td>
<td>D</td>
<td>3, 6</td>
</tr>
<tr>
<td>Training in the recognition and management of anaphylaxis, including use of adrenaline auto-injectors, should be offered to all professionals dealing with patients at risk of anaphylaxis.</td>
<td>IV</td>
<td>C</td>
<td>115</td>
</tr>
<tr>
<td>Training packages should be developed with the target groups.</td>
<td>V</td>
<td>D</td>
<td>Expert opinion</td>
</tr>
<tr>
<td>Training should cover allergen avoidance, symptoms of allergic reactions, when and how to use an adrenaline auto-injector and what other measures are needed within the context of an anaphylaxis management plan.</td>
<td>V</td>
<td>D</td>
<td>3, 6, 79, 125</td>
</tr>
<tr>
<td>Training may involve more than one session to allow revision, an interactive scenario-based approach, a standardized program with manual and educational material and simulation tools. Content and language should be tailored to be understood and memorized.</td>
<td>V</td>
<td>D</td>
<td>3, 126</td>
</tr>
<tr>
<td>PSYCHOLOGICAL INTERVENTIONS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational interventions should ideally incorporate psychological principles and methods to address anxiety so that children and families may function well at home, at school/work, and socially despite their risk of future reactions and should ideally be part of their educational training. This can be done in a group format. Some patients, with severe anxiety of ongoing duration, may need more in-depth one to one psychological intervention.</td>
<td>V</td>
<td>D</td>
<td>110, 123, 124</td>
</tr>
</tbody>
</table>

anaphylaxis with food, latex, aeroallergens such as animals or other unavoidable triggers (C); (ii) exercise-induced anaphylaxis (C); (iii) previous idiopathic anaphylaxis (C); (iv) co-existent unstable or moderate to severe, persistent asthma with food allergy (C); (v) venom allergy in adults with previous systemic reactions (unless receiving maintenance VIT) and children with more than systemic cutaneous reactions (C); and (vi) underlying mast cell disorder and any previous systemic reaction (C). The asthma indication is extrapolated from data emerging from retrospective studies (15, 83-86).

There are a large number of relative indications based on case series or expert opinion (Box 12). As a guide, the presence of one should lead to the consideration of the prescription of an adrenaline auto-injector; in the presence of two or more, strong consideration should be given to prescription; a specialist allergy review may help to balance the advantages and disadvantage of prescribing. Prescription practices differ considerably (87) and there may be additional local indications such as lipid transfer protein sensitisation in the Mediterranean region.
There are no high quality data to help decide how many adrenaline auto-injectors should be available to individual patients. The percentage of patients who required a further dose of intramuscular adrenaline after the administration of an auto-injector was 0-15-32% in different patient groups (15, 83, 84, 61, 88-89) (Box 13) with the additional adrenaline given by healthcare professionals in over 80% of cases. Co-existent asthma was found to be a risk factor for additional adrenaline in one study (84). The challenge is therefore to identify the patients who need to have access to more than one auto-injector. Indications for two auto-injectors are suggested in Box 14. There may also be practical, psychological or policy considerations as to why a specific patient needs more than one auto-injector.

Immunomodulatory approaches

Venom immunotherapy

Systematic reviews (90-92) and meta-analyses (93) have demonstrated the effectiveness of subcutaneous venom immunotherapy (VIT) in children and adults (A). Patients treated with VIT have a better health-related quality of life than those just provided with an adrenaline auto-injector (94, 95). Subcutaneous VIT is therefore recommended in venom allergy for both children and adults with anaphylaxis plus adults with systemic cutaneous reactions (A). Some children with cutaneous sting reactions, where VIT is not indicated, may benefit from having access to an autoinjector (56). The recent systematic review has found VIT to only be cost-effective in populations at high risk of further exposure (93) but the analysis did not incorporate quality of life (96). Rush protocols (i.e. over a few days) are as equally efficacious as slower regimens (97). More adverse effects have been reported with an ultra-rush (few hours) compared to a rush protocol (52) and with rush compared to cluster protocols (98).

Drug desensitization

Drug desensitization is defined as the induction of a temporary state of clinical tolerance of a compound responsible for a hypersensitivity reaction. It is undertaken by administering increasing doses of the medication concerned (e.g. antibiotic, insulins, sulphonamides, chemotherapeutic and biological agents) over a short period of time (from several hours to a few days), until the total cumulative therapeutic dose is achieved and tolerated. It should only be used by trained doctors when alternatives are less effective, not available or contraindicated after considering the risks and benefits. It is mainly undertaken in IGE-mediated reactions, but also in reactions where drug-specific IGE have not been demonstrated (e.g. acetyl salicylic acid). Desensitization induces a temporary tolerant state, which can only be maintained by continuous administration of the medication.
### Box 12  Indications for prescription an adrenaline auto-injector

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABSOLUTE INDICATIONS FOR AT LEAST ONE ADRENALINE AUTO-INJECTOR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous anaphylaxis triggered by food, latex or aeroallergens</td>
<td>IV</td>
<td>C</td>
<td>127, 128</td>
</tr>
<tr>
<td>Previous exercise-induced anaphylaxis</td>
<td>IV</td>
<td>C</td>
<td>58</td>
</tr>
<tr>
<td>Previous idiopathic anaphylaxis</td>
<td>IV</td>
<td>C</td>
<td>61</td>
</tr>
<tr>
<td>Co-existing unstable or moderate to severe, persistent asthma and a food allergy*</td>
<td>IV</td>
<td>C</td>
<td>15, 83, 84, 85, 86</td>
</tr>
<tr>
<td>Venom allergy in adults with previous systemic reactions (not receiving maintenance VIT) and children with more than cutaneous/mucosal systemic reactions</td>
<td>IV</td>
<td>C</td>
<td>56, 129, 130</td>
</tr>
<tr>
<td>Underlying mast cell disorders or elevated baseline serum tryptase concentrations together with any previous systemic allergic reactions to insect stings, even in VIT treated patients</td>
<td>IV</td>
<td>C</td>
<td>52, 56, 103, 130</td>
</tr>
<tr>
<td><strong>CONSIDER PRESCRIBING AT LEAST ONE ADRENALINE AUTO-INJECTOR WITH ANY OF THE FOLLOWING ADDITIONAL FACTORS (ESPECIALLY IF MORE THAN ONE IS PRESENT):</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous mild-to-moderate allergic reaction* to peanut and/or tree nut</td>
<td>IV</td>
<td>C</td>
<td>51, 79</td>
</tr>
<tr>
<td>Teenager or young adult with a food allergy*</td>
<td>IV</td>
<td>C</td>
<td>22, 46, 63, 45, 131</td>
</tr>
<tr>
<td>Remote from medical help and previous mild to moderate allergic reaction to a food, venom, latex or aeroallergens</td>
<td>V</td>
<td>D</td>
<td>131 Expert opinion</td>
</tr>
<tr>
<td>Previous mild-to-moderate allergic reaction to traces of food*</td>
<td>V</td>
<td>D</td>
<td>22, 45, 46, 63, 131</td>
</tr>
</tbody>
</table>

*excluding pollen food syndrome (oral allergy syndrome)

### Box 13  Rate of usage of adrenaline auto-injectors by patients

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study design</th>
<th>Auto-injector prescription</th>
<th>Used an auto-injector during follow up*</th>
<th>Reactions where initial intramuscular adrenaline dose was followed by additional doses**</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>Retrospective clinic population</td>
<td>All</td>
<td>4% (41/969) over a 12 month period</td>
<td>32% (13/41)</td>
</tr>
<tr>
<td>88</td>
<td>Retrospective clinic population</td>
<td>All</td>
<td>22% (15/68) over a 20 month period</td>
<td>15% (2/13)</td>
</tr>
<tr>
<td>89</td>
<td>Prospective clinic population</td>
<td>Not all</td>
<td>3% (23/785) over an average of 48 months</td>
<td>0% (0/23)</td>
</tr>
<tr>
<td>84</td>
<td>Prospective clinic population</td>
<td>Not all</td>
<td>19% (78/413) over an average of 24 month</td>
<td>19% (18/95)</td>
</tr>
<tr>
<td>15</td>
<td>Patient survey</td>
<td>Not all</td>
<td>27% (500/1885)</td>
<td>18% (90/500)</td>
</tr>
<tr>
<td>83)</td>
<td>Patient survey</td>
<td>Not all</td>
<td>35% (22/63)</td>
<td>18% (4/22)</td>
</tr>
</tbody>
</table>

*Refers to individual patients. **Refers to individual allergic reactions (often more than one per patient). Additional doses were usually given by a healthcare professional.
Food oral immunotherapy
There are currently no established oral immunotherapy treatment protocols for food-induced anaphylaxis. Recent data suggest that immunotherapy may increase the amount of a tolerated dose over time (99). Significant systemic side effects can occur and currently these protocols are not recommended in clinical practice (see related food allergy guidelines (77) (Chapter 1.5)).

Prophylaxis
Adrenaline admixture with snakebite anti-venom
The use of subcutaneous adrenaline alone as a pre-medication with snakebite anti-venom reduces the risk of anaphylaxis to the snake anti-venom administration (100, 101) (A). The use of hydrocortisone alone does not reduce severe adverse reaction to snake anti-venom (102) (A).

Pharmacological interventions for the prevention of anaphylaxis to iodinated contrast media
The routine use of prophylactic systemic pre-medication (H1- and/or H2-antihistamines or glucocorticosteroids) cannot be recommended in unselected people undergoing procedures with radio-contrast media as they do not prevent life-threatening reactions (103) (A). There are no available data to support the use of premedication in patients with a previous reaction to another allergen (104).

Training
Who should be trained
As anaphylaxis usually occurs in the community (105-107), all patients at risk of anaphylaxis and their caregivers should be provided with educational resources and training to be able to self-manage reactions ideally from the time of diagnosis (D) (Box 9). Adolescent patients require particular attention given the challenges associated with this period of life (108-111).

What training should cover
Training should cover patient-specific avoidance strategies at home, in the social environment and when traveling (112) (D), recognition of symptoms and warning signals, when and how to administer self-injectable adrenaline and other measures needed to manage the reaction (e.g. call for help, positioning) (D). Training should emphasize the need to continually carry the auto-injector where one has been prescribed (113) (D).

How they should be trained
Several studies indicate that for most patients, the standard prescription and formal instruction on how to prevent and treat anaphylaxis by a physician are insufficient to achieve compliance with respective practical measures, including carrying an adrenaline auto-injector (114) and appropriately using it (61).
This is compounded by the inability of many clinicians to correctly use an adrenaline auto-injector (3, 115). Training should be offered to all professionals dealing with patients at risk of anaphylaxis (C). Educational training has been shown to be clinically effective in chronic allergic diseases such as asthma and atopic eczema or dermatitis (116, 117). Patient education programs are especially effective when using a written action plan (118), a multidimensional and multidisciplinary approach (119), or involved repeated regular medical reviews (120) in other conditions. A multi-disciplinary approach (80) and the provision of educational printed and online materials for food allergy (121) have both been shown to improve knowledge, correct use of auto-injectors and reduce reactions using a before and after study design. Repeated instructions on how to use an adrenaline auto-injector improved correct use in one center (122).

**Psychological interventions**

Information about the future risk of anaphylaxis may lead to stress and anxiety in patients and caregivers (110, 123, 124). Research suggests that this should be addressed by alleviating uncertainty using psychological principles and methods to maximize quality of life as part of the educational training (123) (Box 11) (D). This can be done in a group format. Some patients, with severe anxiety of ongoing duration, may need more in-depth one to one psychological intervention (123) (D).

**Summary and future perspectives**

Anaphylaxis is an important clinical emergency which all healthcare professionals should be able to recognise and manage. Anaphylaxis is a clinical diagnosis based on a constellation of presenting features. Allergy tests are usually helpful in accurately identifying the trigger. First-line treatment is intramuscular adrenaline, which may be repeated if required. Second-line interventions include removing the trigger, calling for help, correct positioning of the patient, high flow oxygen, intravenous fluids, inhaled short-acting bronchodilators and nebulized adrenaline. The evidence base for these and other potential interventions is neither comprehensive nor robust. Patients should be monitored after recovery to observe for possible biphasic reactions. Before discharge, an assessment should be made of the risk of further reactions; where appropriate, the patient should be equipped with an adrenaline auto-injector. The absolute indications for an adrenaline auto-injector are (i) previous anaphylaxis with food, latex, aeroallergens such as animals and other unavoidable triggers; (ii) previous exercise-induced anaphylaxis; (iii) previous idiopathic anaphylaxis; (iv) co-existent unstable or moderate to severe, persistent asthma with food allergy; (v) untreated venom allergy in adults with previous systemic reactions (unless on maintenance VIT) and children with more than systemic cutaneous reactions; and (vi) underlying mast cell disorder and any previous systemic reaction. Specialist allergy follow-up is essential to investigate possible triggers as well as potential co-factors, to perform a risk assessment, prevent future episodes by developing personalized risk reduction strategies, including allergen immunotherapy where indicated, as well as a personalised emergency response plan for future allergic reactions. Patients with food allergy should also have advice from a dietitian. Training the patient and caregivers is essential and should cover avoidance strategies, recognition of symptoms and warning signals, when and how to administer medication including self-injectable adrenaline. Other professionals within healthcare, education and childcare should also be trained to recognize and appropriately manage anaphylaxis.

Two recent, related EAACI systematic reviews of the anaphylaxis literature (1, 2) have revealed a lack of high quality evidence in this area preventing the development of firm recommendations. It is important that these gaps are prioritized to maximize the benefit of future research to patient care (132). Large prospective cohort studies of patients at risk of anaphylaxis in real life settings are required to provide a clearer understanding of the magnitude of risk associated with each factor to allow us to personalize avoidance advice and auto-injector prescription (Box 15). For patients experiencing anaphylaxis, we need further pharmacokinetic studies to determine the optimal dose and dosing interval, especially for adult patients (Box 15). Further work on other routes of adrenaline administration should be encouraged as adjuvants to intramuscular adrenaline. Additionally, randomized controlled studies are required to assess the effectiveness of systemic glucocorticosteroids in preventing late manifestations of anaphylaxis and whether the addition of antihistamines improves the respiratory and/or cardiovascular features of anaphylaxis. Finally we need evidence to assess the
## Box 15 Anaphylaxis: gaps in the evidence

<table>
<thead>
<tr>
<th>Gap</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANAPHYLAXIS EPIDEMIOLOGY AND CLINICAL PRESENTATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinical definition and diagnostic criteria for allergic anaphylaxis that are easy to use in practice by emergency room medical staff.</td>
<td>Consensus process</td>
<td>2</td>
</tr>
<tr>
<td>Universally accepted, epidemiological definition and associated coding criteria to allow accurate modeling of anaphylaxis cases.</td>
<td>Consensus process</td>
<td>3</td>
</tr>
<tr>
<td>Accurate estimation of the incidence, prevalence, burden and mortality rate of anaphylaxis in different populations across Europe.</td>
<td>Application of new definition and criteria plus study of routine clinical diagnostic data</td>
<td>4</td>
</tr>
<tr>
<td>Clearer understanding of the magnitude of risk factors for future occurrence of anaphylaxis.</td>
<td>Large prospective cohort studies of patients at risk of anaphylaxis</td>
<td>1</td>
</tr>
<tr>
<td><strong>EMERGENCY MANAGEMENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-line intervention: adrenaline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal dose and dosing intervals of intramuscular adrenaline in patients experiencing anaphylaxis.</td>
<td>Pharmacokinetics studies</td>
<td>1</td>
</tr>
<tr>
<td>Role of other routes of adrenaline (e.g. inhaled, sublingual) in anaphylaxis.</td>
<td>Randomized controlled trials</td>
<td>2</td>
</tr>
<tr>
<td>Data comparing the pharmacokinetics of different adrenaline auto-injector devices</td>
<td>Randomized controlled trials</td>
<td>4</td>
</tr>
<tr>
<td>Second-line interventions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role of second-line drugs in the treatment of anaphylaxis, namely oxygen and inhaled beta-2 agonists</td>
<td>Randomized controlled trials</td>
<td>5</td>
</tr>
<tr>
<td>Comparative efficacies of crystalloids and colloids in the treatment of cardiovascular instability during anaphylaxis</td>
<td>Randomized controlled trials</td>
<td>6</td>
</tr>
<tr>
<td>Third-line interventions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role of third-line interventions in the treatment of anaphylaxis, namely H1-antihistamines and systemic glucocorticosteroids.</td>
<td>Randomized controlled trials</td>
<td>3</td>
</tr>
<tr>
<td><strong>LONG-TERM MANAGEMENT, TRAINING AND PSYCHOLOGICAL INTERVENTIONS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anaphylaxis management plans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple different anaphylaxis management plans and emergency action plans in use.</td>
<td>Consensus process with all stakeholders</td>
<td>5</td>
</tr>
<tr>
<td>Evidence on the effectiveness of anaphylaxis management plans, particularly in different subgroup (e.g. age, allergy type, different risk levels).</td>
<td>Pragmatic large randomized controlled trials</td>
<td>2</td>
</tr>
<tr>
<td>Evidence on the utility of management plans (e.g. with quality of life questionnaires)</td>
<td>Pragmatic randomized controlled trials</td>
<td>7</td>
</tr>
</tbody>
</table>
### ADRENALINE AUTO-INJECTORS

<table>
<thead>
<tr>
<th>Gap</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who should have an adrenaline auto-injector and how many should they have access to?</td>
<td>Large prospective studies, well phenotyped participants, clear criteria for anaphylaxis</td>
<td>1</td>
</tr>
<tr>
<td>Whether a stock supply of adrenaline auto-injectors in locations such as schools might improve the management of anaphylaxis in the community?</td>
<td>Large cluster randomized controlled trials</td>
<td>8</td>
</tr>
</tbody>
</table>

### VENOM IMMUNOTHERAPY

<table>
<thead>
<tr>
<th>Gap</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is unclear if venom immunotherapy is able to prevent fatal reactions, because of the rarity of this outcome</td>
<td>Controlled studies would be unethical</td>
<td></td>
</tr>
<tr>
<td>Cost-effective evaluation of the treatment in relation to quality of life rather than survival rate</td>
<td>Health economic analysis</td>
<td>9</td>
</tr>
<tr>
<td>Comparative studies on the effect of different build-up protocols (traditional versus rush and ultra-rush) with the same extract focusing on safety</td>
<td>Randomized controlled trials comparing approaches</td>
<td>10</td>
</tr>
</tbody>
</table>

### PROPHYLACTIC INTERVENTIONS

<table>
<thead>
<tr>
<th>Gap</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studies to compare the effectiveness of prophylactic pre-medication to prevent life-threatening reactions due to iodinated contrast media in patients with a history of a previous immediate reactions or potential risk factors for reactions</td>
<td>Large randomized controlled trial</td>
<td>11</td>
</tr>
<tr>
<td>Studies looking at the impact of other immunomodulatory interventions on reducing the risk of further episodes of anaphylaxis, for example monoclonal anti-IgE (e.g. omalizumab).</td>
<td>Randomized controlled trials to assess</td>
<td></td>
</tr>
</tbody>
</table>

### TRAINING

<table>
<thead>
<tr>
<th>Gap</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence on the efficacy of training of patients and direct caregivers/parents of children and other groups such as teachers, day care workers, nurses, and physicians.</td>
<td>Randomized controlled trial to assess impact of training</td>
<td>3</td>
</tr>
<tr>
<td>Evidence on the optimal content, trainers (e.g. physicians, allergy specialist dietitians), duration, repetition and format of training and whether it should vary for patients of different ages and different future risk.</td>
<td>Development of training program with stakeholders and formal assessment of effectiveness</td>
<td>4</td>
</tr>
</tbody>
</table>

### PSYCHOLOGICAL INTERVENTIONS

<table>
<thead>
<tr>
<th>Gap</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short- and long-term efficacy of different psychological interventions and their influence on quality of life, knowledge, anxiety, compliance with carriage of in-date adrenaline auto-injectors, performance in an emergency situation, and social functioning in at risk patients and their caregivers and how differing personalities impact the efficacy of the interventions.</td>
<td>Randomized controlled trial assessing impact of approach</td>
<td>6</td>
</tr>
</tbody>
</table>
effectiveness of training and anaphylaxis management plans in improving outcome in patients (Box 15).

Acknowledgements
We would like to acknowledge the support of EAACI and the EAACI Food Allergy and Anaphylaxis Guidelines Group in developing these guidelines. We would like to thank Toby Pitts-Tucker and Catherine Crowley for their assistance in preparing the guidelines. We would also like to thank our expert panel and everyone who provided comments on the draft guidelines (in particular Moira Austin, Carlo Caffarelli, Rollo Clifford, Lene Heise Garvey, Lars Gottberg, Joanna Lange, Barbara Rogala, Francesca Saretta, Peter Stadning, Alessandra Ometto and David Reading) and the EAACI Executive Committee for their helpful comments and suggestions.

Authors’ contribution
Antonella Muraro, Chair of the EAACI Food Allergy and Anaphylaxis Guidelines Initiative, has steered and coordinated the publication. Graham Roberts facilitated the anaphylaxis guidelines group and edited the guidelines document with support from Margitta Worm. M. Beatrice Bilò, Knut Brockow, Montserrat Fernández-Rivas, Alexandra F. Santos, Zaraquiza Zolkipli and Aziz Sheikh coordinated drafting of the evidence table, recommendations, gaps and text for specific sections. Sangeeta Dhami and Sukhmeet Panesar undertook the supporting systematic reviews under the supervision of Aziz Sheikh. All authors participated in the discussion of the evidence table, recommendations, gaps and specific sections and approved the final version.

Conflicts of interest
Graham Roberts has provided scientific advice for Danone and ALK-Abelló; Thermo Fisher and ALK-Abelló have provided consumables for his research activities. Antonella Muraro has provided scientific advice for Meda. Margitta Worm has provided scientific advice for ALK-Abelló. M. Beatrice Bilò has provided scientific advice for Meda. Knut Brockow has provided scientific advice for ALK-Abelló, Meda, Thermo Fisher and Stallergenes. Montserrat Fernández-Rivas has provided scientific advice to GSK; ALK-Abelló has provided consumables for her research activities. Carsten Bindselev-Jensen has received funding from Thermo Fisher, HAL, Stallergenes and Anergis, ALK, Novartis, MSD, Schering-Plough for his research activities. Victoria Cardona has provided scientific advice for ALK-Abelló. Pascal Demoly has provided scientific advice for Stallergenes, ALK-Abelló, Circassia, Allergopharma, Chiesi, Menarini and Pierre Fabre Médicament, Tony DuBois has provided scientific advice for ALK-Abelló and received funding from ALK-Abelló to support his research activities. Audrey DunnGalvin has received funding from Novartis for her research. Philippe Eigenmann has provided scientific advice for Danone, Novartis, ALK, DBV technologies and Stallergenes; he has received funding for research activities from LETI, Nestlé and Thermo Fisher. Susanne Halken has provided scientific advice for ALK-Abelló. Marek Jutel has been an investigator for clinical studies led by Allergopharma, Stallergenes, Novatis, GSK and Medimmune. Franziska Ruéff has been an investigator for clinical studies led by Allergopharma, HAL, Novartis and Pierre Fabre and has received travel grants and honoraria as a speaker from ALK-Abelló, Bencard, HAL, Novartis and Thermo Fisher. Frans Timmermans has received unrestricted grants from ALK-Abello, MSD, MEDA for the activities of European Anaphylaxis Taskforce – Nederlands Anafylaxis Netwerk which he manages. Berber Vlieg-Boerstra has provided scientific advice for Danone and Mead Johnson; she has received research grants from Nutricia Advanced Medical Nutrition and ALK-Abelló, Sukhmeet Panesar, Sangeeta Dhami and Aziz Sheikh have received funding for coordinating guidelines production, and generating the systematic reviews from EAACI. Aziz Sheikh has provided scientific advice to ALK-Abelló, Meda, Lincoln Medical, Thermo Fisher, Pfizer and Stallergenes; he is on the Anaphylaxis Campaign UK’s Scientific Committee, World Allergy Organization’s Anaphylaxis Special Committee, UK Resuscitation Council’s Anaphylaxis Committee and the BSACI’s Standard of Care Committee. Laurie Harada works for Anaphylaxis Canada whose educational activities have been supported by Pfizer and Sanofi. Alexandra F. Santos, Zaraquiza Zolkipli, Cezmi Akdis, Kirsten Beyer, Abdul Bellou, Gideon Lack, Bodo Niggemann, Andy Clark and Thomas Werfel have no conflict of interests.

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5.1

MANAGING PATIENTS WITH FOOD ALLERGY IN THE COMMUNITY

EAACI GUIDELINES

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The European Academy of Allergy and Clinical Immunology (EAACI) Food Allergy and Anaphylaxis Guidelines, managing patients with food allergy in the community, intend to provide guidance to reduce the risk of accidental allergic reactions to foods in the community. This document is intended to meet the needs of early childhood and school settings as well as providers of non-pre-packaged food (e.g. restaurants, bakeries, take-away, deli counters, and fast-food outlets) and targets the audience of individuals with food allergy, their families, patient organizations, the general public, policy makers and allergists.

Food allergy is the trigger of anaphylaxis in the community. Providing children and caregivers with comprehensive information on food allergen avoidance, and prompt recognition and management of allergic reactions are of the utmost importance. Provision of adrenaline auto-injector devices and education on how and when to use these, are essential components of a comprehensive management plan.

Managing patients at risk of anaphylaxis raises many challenges, which are specific to the community. This includes the need to interact with third parties providing food (e.g. school teachers and restaurant staff) to avoid accidental exposure and to help individuals with food allergy to make safe and appropriate food choices. Education of individuals at risk and their families, their peers, school nurses and teachers as well as restaurant and other food retail staff can reduce the risk of reactions. Increased awareness among policy makers may improve decision making on legislation at local and national level.

**BACKGROUND**

Food allergy reactions commonly occur outside the home (1) (Box 1). This section of EAACI Food Allergy and Anaphylaxis Guidelines is intended to provide guidance to all stakeholders in order to reduce the risk of accidental allergic reactions to foods in the community. These guidelines are therefore intended to assist those working in school and early childhood settings (e.g. kindergarten) as well as providers of non-pre-packaged food (e.g. restaurants, bakeries, take-away, deli counters, and fast-food outlets). Furthermore, we hope it will help children with food allergy, their families, schools, and their specialist and non-specialist healthcare providers (Table 1). These guidelines have been prepared by EAACI’s Taskforce on the Community and builds on the previous EAACI Position Paper on Management of the Allergic Child at School (2).

**METHODS**

These guidelines were produced using the Appraisal of Guidelines for Research & Evaluation (AGREE II) approach (4, 5). This is a structured approach to guideline production that is designed to ensure appropriate representation of the wide range of stakeholders, a careful search for and critical appraisal of the relevant literature, a systematic approach to the formulation and presentation of recommendations, and steps to ensure that the risk of bias is minimized at each step of the process. We provide below an overview of the approach used.

**Clarifying the scope and purpose of the guidelines**

The process began in January 2012 with a meeting to discuss the overall approach to guideline development. This included detailed discussions on the main aims of the guidelines, the target conditions, agreeing the intended end-user for the recommendations, agreeing the intended end-user group, and ensuring adequate professional and lay representation in the guidelines development process.

**Ensuring appropriate stakeholder involvement**

Participants represented 20 European countries,

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### Table 1 Target audience

<table>
<thead>
<tr>
<th>Audience</th>
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<tbody>
<tr>
<td>Children with food allergy and their caregivers</td>
</tr>
<tr>
<td>Healthcare providers</td>
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<tr>
<td>Food service staff and managers</td>
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<tr>
<td>Early childhood settings staff and managers</td>
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<tr>
<td>School principals, teachers, school staff and volunteers</td>
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<tr>
<td>Patient organizations</td>
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<tr>
<td>Government and policy makers</td>
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</table>

### Box 1 Key terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td><strong>Food allergy</strong></td>
<td>An adverse reaction to food triggered by an immunological mechanism, involving specific IgE (IgE mediated) or cell-mediated mechanisms (non IgE mediated) or both IgE and cell mediated mechanisms (mixed IgE and non IgE mediated). Food allergy is a subgroup of food hypersensitivity reactions.</td>
</tr>
<tr>
<td><strong>Anaphylaxis</strong></td>
<td>“Severe, life-threatening generalized or systemic hypersensitivity reaction”(3) which is characterized by being rapid in onset with life-threatening airway, breathing or circulatory problems, usually associated with skin and mucosal changes</td>
</tr>
<tr>
<td><strong>Adrenaline (epinephrine)</strong></td>
<td>Drug with combined alpha- and beta-agonist causing peripheral vasoconstriction (reversing hypotension and mucosal oedema), increased rate and force of cardiac contractions (reversing hypotension), reversal of bronchoconstriction and reduction in release of inflammatory mediators in case of anaphylaxis.</td>
</tr>
<tr>
<td><strong>Adrenaline auto-injectors</strong></td>
<td>Devices that patients, caregivers or professionals can be trained to use to give a pre-defined dose of intramuscular adrenaline</td>
</tr>
<tr>
<td><strong>Personalized emergency management plan</strong></td>
<td>A written plan tailored to the individual patient’s clinical characteristics of reaction, to be implemented when a reaction occurs</td>
</tr>
</tbody>
</table>
Formulating recommendations

The following recommendations are the result of expert opinion consensus following previous systematic reviews of literature on epidemiology, diagnosis and management of food allergy and anaphylaxis (6, 7, 8, 9) and extensive narrative review of the relevant literature (Box 2). They result also from consultations with all the stakeholders involved in management of food allergy and anaphylaxis, such as primary care physicians, nurses, dietitians, patient organizations and teachers associations.

Experts identified the resource implications of implementing the recommendations, barriers and facilitators to the implementation of each recommendation, advised on approaches to implementing the recommendations and suggested audit criteria that can help with assessing organizational compliance with each recommendation.

Peer review

A draft of these guidelines were externally peer-reviewed by experts from a range of organizations, countries and professional backgrounds. All feedback was considered by the Community Task Force and, where appropriate, final revisions were made in the light of the feedback received. We will be pleased to continue to receive feedback on these guidelines, which should be addressed to the first author.

Identification of evidence gaps

The process of developing these guidelines identified a number of evidence gaps and we plan in future to prioritize the questions that the Community Task Force believes should be urgently addressed through formal consensus building techniques. We plan furthermore to draft outline research briefs that funders can use to commission research on these questions.
WHY THE COMMUNITY IS IMPORTANT

Food allergy is a common and increasing problem (11, 12) with the main burden occurring in childhood (13). In Europe, at least 25% of school-age children live with allergic disease, and food allergy affects up to 4-7% of primary school children (6). The estimate will vary depending on point or lifetime prevalence and whether this is self-reported, based on oral food challenge or other methods. The pooled lifetime and point prevalence of self-reported FA were 17.3% (95% CI: 17.0-17.6) and 5.9% (95% CI: 5.7-6.1), respectively. The point prevalence of sensitization to ≥1 food as assessed by specific IgE was 10.1% (95% CI: 9.4-10.8) and skin prick test 2.7% (95% CI: 2.4-3.0), food challenge positivity 0.9% (95% CI: 0.8-1.1).

Food allergy, particularly to peanuts, tree nuts, egg and milk, is the leading cause of anaphylaxis (14-17). Allergen avoidance education is often targeted at avoidance within the home, with less emphasis on how to avoid community exposure. Anaphylaxis often presents at home, and this as an important situation to manage (1). However, there is also significant risk from community exposure. The location for anaphylaxis to occur in the community is school or kindergarten, accounting for 16-22% of reactions (18, 19-23). Between 10-18% of food allergy or reactions occur at school (1, 24). In a United Kingdom (UK) survey, 61% of schools had at least one child at risk of anaphylaxis (i.e. had a reported history of anaphylaxis or carried an AAI (25). Reactions also occur in a wide variety of other community locations including restaurants, sports fields, beaches, and gymnasiums (21). Fatalities due to food allergy are equally likely to occur at home or in community locations such as a restaurant/take away (26), friend's home, school/nursery (27-29), camp and work (30, 31).

The management of food allergic children should therefore to protect against the risk of allergen exposure outside the home. Avoidance of community reactions depends on complex factors and interaction with third parties providing food (e.g. schools) when parents are not present. Anaphylaxis is in adolescents and young adults, an age when they begin to take over responsibility for making food choices outside the home (32), and carrying emergency medication (33-36). Improved education of individuals at risk and their families, peers, school staff and restaurant and other food service staff about reducing risk can help to prevent fatalities (18). Increased awareness of policy makers may improve care at local and national levels. Harmonized legislation is urgently required for the generic availability and administration of adrenaline at school as well as for educational multidisciplinary programmes aimed at general practitioners and targeting the family as a whole, the restaurant, canteen and school staff (37).

FAMILIES, CAREGIVERS AND THE ALLERGIST

Families of children require guidance on managing this potentially long-lasting condition, balancing safety against social and emotional restrictions. Equal weight should be given to protecting children against community and home reactions. Parents and caregivers have primary responsibility for coordinating care for their children. As children reach adolescence, they begin to make food choices by themselves outside the home, and take responsibility for carrying their own emergency medication. This coincides with the time of life severe reactions and deaths due to anaphylaxis. Education should be focused on providing a comprehensive package of age-appropriate avoidance, advice, provision and training in how and when to use emergency medication.

The first principle is correct diagnosis of the allergy by clinical history, serum specific IgE and skin prick testing and challenge, if necessary, to identify relevant trigger and tolerated foods (7, 8). The allergist and or the dietitian should provide comprehensive advice on allergenic foods to be avoided, interpretation of food allergen labelling (including precautionary labelling) and identification of potential sources of cross-contamination. Patients and their families should be advised of the common pitfalls and situations where accidental reactions are particularly frequent or severe, and contingencies for these situations should be discussed. Advice should include guidance for relevant community-specific situations, for example, how to manage food allergy with reference to school meals, school camps or social gatherings. Management should also focus on good control of co-existing asthma. Other allergic conditions such as eczema and allergic rhinitis should also be addressed.

The use of comprehensive personalized emergency management plans (PEMP) is associated with a
decreasing frequency of severe reactions following their implementation (31, 38). Regular follow-up is an essential part of any management plan. The ability of parents to assess the risk and manage their child’s condition is highly dependent on their own knowledge, attitudes, and beliefs about food allergy (13). Not surprisingly, misconceptions are held about prevalence and triggers. Also, many families report an adverse effect of the food allergy on their personal relationships, with some experiencing outright hostility from others when trying to accommodate their child’s food allergy (39).

Provision of adrenaline auto-injector devices to those at risk of anaphylaxis is an essential part of the comprehensive PEMP. Indications for provision of AAIs are discussed in detail in the anaphylaxis (9). According to the Health Council of the Netherlands 1450 to 1700 children in the Netherlands are prescribed an adrenaline auto-injector device (AAI) yearly 50-75% of children two devices, one on their person and one stored at day care or school (40). However, an alarming under-prescription of AAIs was reported in school-going adolescents: although the auto-injector was indicated in 3.0%, only 0.09% of the adolescent evaluated owned a device (41). In a study of children from 14 allergy clinics throughout UK, only 16.7% used their prescribed AAI during anaphylaxis (42). These data emphasize the importance of repeated education and assessment of the knowledge on how and when to use of AAI devices (9).

Education is clearly important. Factors associated with greater knowledge are a prior practical demonstration, consultation with an allergy specialist rather than a general physician and independently seeking additional information from a patient organization (43). Factors correlating with confidence to administer auto-injectors are prior administration, regular training and empowerment by healthcare professionals to manage a severe allergic reaction (44).

**School**

Food allergy is a common health issue in the school setting (45, 46) will be exposed to when out of their parents’ direct care and require adrenaline administration. All schools should therefore have a policy to protect such children. The reality is that many facilities are poorly prepared to protect students. Essential components of policies for the prevention of food allergen exposure are often missing (1, 47). Teachers have poor knowledge of anaphylaxis triggers, symptoms, and adrenaline auto-injectors (23, 48, 49, 50) and PEMPs are not currently consistently provided for the majority of students with food allergy (23).

In one series of school children, only 54% had a personalized emergency management plan, 72% an AAI, and 60% a complete emergency kit (51, 52). Where PEMPs are provided studies have shown that up to two-thirds of patients and caregivers are unable to administer AAI devices, or even have them available (52).

In a study on a large university campus only 6.6% of food allergic students reported always carrying an AAI (48); in addition, only 39.7% avoided a self-identified food allergen (48).

The goals in school are to create a network of support and a self-sustaining environment of awareness that reduces the likelihood of reactions, and enables staff to recognize and treat emergencies. The ideal approach is for schools to develop a formal policy, with the aim of achieving these goals, which is informed by the available expertise (Box 3).

The school principal should take overall responsibility for provision and delivery of the policy. Early liaison with local expertise such as allergists, paediatricians, allergy nurses and patient organizations is essential to the implementation of a well-informed, comprehensive policy. There may be significant barriers to be overcome in this regard as ‘education’ and ‘health’ are often governed by different municipal government bodies. Therefore, fostering a cooperative partnership between doctors, community nurses, dietitians, parents and the school community is essential (50).

A named person should be responsible for development of a personalised care plan (PCP) for individual children. This should ideally be a school nurse, but if not available then another appropriately trained individual (e.g. teacher) could be identified. There may be no such person, in which case the principal is encouraged to seek help in training staff using suitable allergy resources (Box 4). All staff are responsible for implementation of the policy.

Teachers and school staff responsible for student supervision should be properly instructed to recognize the onset of an allergic reaction, including anaphylaxis, and know how and when to get help. In many schools there is a lack of full-time school nurses and teachers

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**Box 3**

- **Provision of adrenaline auto-injector devices:**
  - AAI:
    - 1450 to 1700 children in the Netherlands are prescribed an AAI yearly.
    - 50-75% of children use two devices, one on their person and one stored at day care or school.
  - Under-prescription of AAIs in school-going adolescents: 3.0% indicated, 0.09% owned a device.
  - In UK, only 16.7% used prescribed AAI during anaphylaxis.

- **Education:**
  - Factors associated with greater knowledge: prior practical demonstration, consultation with an allergy specialist, independently seeking additional information.
  - Factors correlating with confidence: prior administration, regular training, empowerment by healthcare professionals.

- **School principal:**
  - Overall responsibility for policy provision and delivery.
  - Liaison with local expertise essential for well-informed policy.

- **Box 4**

  **Allergy resources:**
  - Training for staff.
  - Suitable materials provided.

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feel overwhelmed when the responsibility is placed upon them to care for children. It is imperative that teachers receive a comprehensive and practical educational program on food allergies whether a school nurse is available or not.

Ideally, school nurses should play a key role in coordinating management of students with food allergies. It is essential they themselves have received sufficient training in food allergy. These school nurses can then train the entire school staff. A train-the-trainer anaphylaxis education program providing school nurses with curriculum, lesson plans, teaching-learning activities, and resources for anaphylaxis education of all school staff has been suggested in Europe (and the US) through patient organizations (56, 57) (http://www.anaphylaxis.org.uk)

The nominated individual should adapt the PEMP for each student. Parents need to be included in discussions on school management (including PEMPs) as they are well practiced in managing their child’s food allergy by the time they reach school age. When school staff and parents cannot agree on an important issue, it can be taken to the specialist.

Another important component of the policy is to have systems in place to identify children to school staff, especially catering or new/temporary staff. Any food provided by the school should have clear allergen labelling; menus including allergen information should be available to the families in advance. Appropriate food handling procedures should be put in place to minimise the risk of cross-contamination. A general ‘allergen-ban’ in isolation is inadequate, falling short of a ‘whole school management’ approach to instil allergy awareness throughout the school. Measures in line with these approaches include cleaning faces, hands and the floor after meals, making sure the has own treats.

Bullying, teasing, and harassment of children with food allergy together with denial of their condition is also frequently encountered (53, 54). Policies should be structured around ethical principles of confidentiality (where appropriate), fairness, avoiding stigmatization, and empowerment of those affected (55).

Primary and secondary/tertiary school policies should differ in order to reflect the needs and developmental level of their students. Primary school children tend to be in a more protective environment. In secondary schools pupils should be supported as they become
more responsible for their allergies. During the teenage years adolescents should be positively encouraged to self-manage their condition whilst still in a ‘semi-protected’ environment, in preparation for adulthood (58, 59). An “adolescent-centred” approach empowers secondary pupils in a process that is meaningful and relevant to their lives (60).

Secondary schools should educate the peers of students with food allergy in good practice, risk awareness and management of emergencies. This may help counteract the ignorance, stigma and bullying associated with allergies.

Prompt administration of adrenaline is the first-line treatment for anaphylaxis. Scheduled checks for the availability of AAI’s are essential, to identify AAI expiry and ensure timely replacement, in liaison with the family (61). Quick and easy access to adrenaline is also an issue since in many cases the device is stored in a remote office causing a delay. School policy should specify a protocol to bring the device to the student promptly during an emergency. Storage in the class or cafeteria or other unlocked and easily accessible locations is recommended for primary school students. As soon as the student achieves a proper level of maturity they can be encouraged to self-carry the device.

AAIs are not always subsidized by public health insurance, limiting their availability (62). In such cases government support for reimbursement of adrenaline auto-injectors in low-income households is desirable. Some US and Australian, though not European legislatures, are now permitting the patient non-specific availability of AAIs in schools, which may address this issue of children and adolescents having to always carry their own AAIs. However students will still need to carry their own AAI to protect them from the effects of food sharing and food accidents on the way to and from school, or on school trip (Box 5).

**Providers of non-prepacked foods**

Restaurants and other food establishments, such as bakeries, take-aways, deli counters and fast-food outlets, pose a number of potential dangers for individuals with food allergy, particularly due to cross-contamination and unexpected ingredients. A telephone survey of US patients who suffered reactions to peanut and tree nut in restaurants, bakeries and shops showed that only 45% with previously diagnosed food allergy notified the establishment of their allergy. In the remainder of cases, reported reactions resulted from ingestion of food not intended for them, ingestion of food selected from buffet/food bars, or skin or inhalational contact (e.g. residual food on tables; peanut shells covering floors; being within a metre of the cooking of the food). For 78% of all reported reactions, someone in the establishment knew that the food contained the allergen as an ingredient. In 50% of these incidents, the food item was “hidden” (e.g. in sauces and dressings). In 22% cases, exposures were reported from contamination caused primarily by shared cooking or serving supplies (63).

Social considerations such as peer pressure, embarrassment, stigma, alcohol ingestion, choice and spontaneity may hamper a parent or adolescent’s ability to apply appropriate avoidance behaviour (64). The individual or family should clearly state the allergy to the provider on each occasion and if possible should preview the menu online. This should be repeated on every visit to take account of change in recipes or staff. The food providers have a responsibility to provide clear, comprehensive information on potential allergenic ingredients so the individual/family can make an informed decision about food consumption. Where the risk is unknown, this should also be stated, and the restaurant should be avoided.

At present current food allergen legislation requires any of the 14 EU regulatory allergens, where used as ingredient, to be clearly declared within the ingredients list of prepacked foods (65). From December 2014, the Food Information for Consumers Regulation (EU Regulation No. 1169/2011) will also require businesses selling food sold non-prepacked to provide information about allergenic ingredients deliberately used in the food they serve to consumers. The allergens which have to be declared are mentioned in the Annex II of the Regulation. They include most of the major allergens, but not every food allergen. There are examples of voluntary best practice advice for such businesses (66).

Food preparation and handling techniques in catering establishments can increase the risk of a food allergic reaction due to the possibility of cross-contamination. The frequency of accidental allergic reactions as a result of cross-contamination in food establishments...
Box 5  Families, healthcare professionals, schools, food outlets: recommendations

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>THE INDIVIDUAL / FAMILY</strong></td>
<td></td>
<td></td>
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<tr>
<td>Implement allergen strategies recommended by the allergist, nurse and dietitian</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
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<tr>
<td>both within the home and the wider community</td>
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<tr>
<td>For children, inform the school/early-years settings of the allergy and provide</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
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<tr>
<td>them with a food allergy management plan from the allergist.</td>
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<tr>
<td>Keep regular follow up with the allergist and school nurse and dietitian and</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
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<tr>
<td>forward new copies of treatment plans to the school as they are updated</td>
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<tr>
<td>Monitor medication expiry dates and replace adrenaline auto-injectors as</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
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<tr>
<td>required</td>
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<td><strong>THE ALLERGIST (ALLERGY SPECIALIST OR OTHER HEALTHCARE PROFESSIONAL WITH THE</strong></td>
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<td><strong>APPROPRIATE TRAINING AND COMPETENCY):</strong></td>
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<tr>
<td>Provide a comprehensive food allergy management plan incorporating the</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
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<tr>
<td>following features: diagnosis, risk assessment, allergen avoidance advice,</td>
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<tr>
<td>provision and training in emergency medication, including adrenaline</td>
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<tr>
<td>auto-injectors.</td>
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<tr>
<td>Provide a written management plan incorporating relevant allergen avoidance</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
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<tr>
<td>advice and use of emergency medication PEMP; This should be passed to the</td>
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<tr>
<td>school to form be incorporated into a personalized care plan (PCP).</td>
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<tr>
<td>Liaise with educational services (for children) to develop/maintain a</td>
<td>V</td>
<td>D</td>
<td>Expert consensus</td>
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<td>comprehensive school allergy policy and individual PCPs.</td>
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<tr>
<td><strong>SCHOOLS: RECOMMENDATIONS</strong></td>
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<tr>
<td>The school principal should develop a comprehensive school policy for allergy</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
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<td>aware management and a staff member should be identified to coordinate</td>
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<td>allergy care and liaise with local allergy services.</td>
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<tr>
<td>The school should identify all children with food allergy in its care, and</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
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<tr>
<td>each should have a PCP. The care plan should clearly state which foods are to</td>
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<td>be avoided, and what action is to be taken in the event of an accidental</td>
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<td>reaction.</td>
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<tr>
<td>The school should engage with local allergy specialists to provide input into</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
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<tr>
<td>PCPs, training staff on food allergen avoidance, and how to treat reactions</td>
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<td>PEMP.</td>
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<td>The school should store emergency medication for each child as recommended</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
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<td>by the allergist. Medication should be readily available.</td>
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<tr>
<td>Allergy awareness should be applied to cooking and handling of food anywhere</td>
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<td>D</td>
<td>Expert Opinion</td>
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<td>in the school</td>
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<tr>
<td>The scope of the comprehensive school policy should extend to school trips,</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
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<td>exchanges and excursions</td>
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<tr>
<td><strong>SUPPLIERS AND PROVIDERS OF NON-PACKAGED FOODS:</strong></td>
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<tr>
<td>Seek training and obtain competency in serving customers who have food</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>allergy</td>
<td></td>
<td></td>
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<tr>
<td>Implement policy and procedures to reduce cross-contamination</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td>Provide information to customers about food allergen content or possible cross</td>
<td>IV</td>
<td>D</td>
<td>Expert Opinion</td>
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<tr>
<td>contamination</td>
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</table>
is unknown, though it is frequently encountered in clinical practice. Ignorance of the ingredients in a recipe by serving staff also poses significant risk (67). Good communication between staff preparing food and front-of-house serving staff is essential to prevent this. Some food allergic individuals can react to ingestion of trace levels of the offending food, although highly variable ranges of threshold doses exist. The magnitude of the risk depends, amongst other factors, on the dose of exposure to cross-contaminated foods, and the individual’s threshold reactivity (68). Other co-factors at the time of the reaction such as poor asthma control, type of food allergen, exercise, infection, menstruation, NSAIDs, and alcohol use may contribute to severity (68-71). One study showed that for peanut allergy, threshold levels decreased with increasing age and increasing sIGE (72). However, in most fatal reactions, the allergen was deliberate ingredient in the food and not due present to cross contamination, and adrenaline was not available or not administered (18, 73). Insufficient threshold dose information within the food allergic population restricts the advice on safe levels of contamination allergenic foods.

The need for more training for restaurant staff and consumer caution on staff knowledge gaps remains high. Studies from the US and the UK of an assortment of staff from a wide variety of restaurants and fast-food outlets suggest a high degree of confidence, but a low level of knowledge, and a desire for further training (74-76).

Travelling abroad may be perceived as a potential risky situation for severe food allergic reactions. Difficulties with airlines or restaurants are frequently quoted (76). The data from studies reporting reactions on airplanes is limited (77); but a small number, of reactions occur in this context, some of them severe. Airline companies show inconsistency, e.g. regarding provision of peanuts on board aircraft, and requests for special assistance (78-82). Allergic reactions constituted only 2.2% of medical emergencies during commercial passenger flights in the US (83).

In the survey performed by Greenhawt et al., although 76% of food allergic patients who had an in-flight reaction reported carrying an AAI only 10.6% of these individuals used their device, and overall, only 10% received adrenaline (from the auto-injector or via syringe) as treatment. Despite the reaction, 52.4% reported not making any changes in their behaviour. However some protective behaviour was reported by the other half: 25.7% reported they no longer consume food served on board, 23.8% now clean their personal seating area, and 20% request a peanut or tree nut-free flight. Twelve percent reported no longer flying commercially as a result of this reaction (80).

The approach to eating on an aircraft should be the same as that for any restaurant, ensuring the cabin staff are aware of the allergy (preferably inform the airline before the flight and the cabin staff on the day), and the contents of any meal served during the flight should be carefully checked. Emergency medication should be carried in the aircraft cabin and not packed into the luggage hold.

At the destination, individuals can use a variety of strategies to remain safe including visiting familiar environments, carrying allergy information cards in the host language and possibly preparing their own food (84). They should also carry a sufficient supply of emergency medication, bearing in mind it may be difficult to replace, and be prepared to use it.

**General Public**

The general public plays a significant role in the well being of individuals with food allergy. The emergence of food allergy as a significant public health problem has been relatively recent and is accompanied by increasing interest from the mass media and the commercial sector, as policy-makers respond to the demands of affected individuals (84). Food allergy has become an important issue on the regulatory agenda, particularly in the UK, Canada, the USA, New Zealand and Australia (85). In order to respond appropriately to the growing prevalence of food allergies, decision-makers must balance protecting the affected population, whilst accommodating the general public’s needs.

Improved food allergy knowledge among the general public is desirable. A web-based survey of the general US population showed that familiarity and prior training in food allergy management were associated with higher knowledge scores. However, respondents tended to minimize the stigma associated with food allergy and oppose food allergy policies in schools (86). The introduction of public health policies to protect food-allergic individuals should be based on the best available data and expert consensus. Currently, many policies and regulations are being implemented in
public spaces (schools, restaurants) despite the lack of scientific consensus (87). Consequently, these policies are often perceived as extreme in the literature, in the media, and by the non-allergic population (88). The inflated perception of risk for severe food allergies in the general population (87, 89) has resulted in several debates related to protection versus rights, particularly around the policies developed in response to the disproportionate burden of food allergies in children (90).

In addition social exclusion (such as parents to invite an a child with allergies, prohibited trips and activities or reduced career options in the longer term) is a growing problem that needs to be addressed at the societal level. In the meantime, careful planning such as training the staff who will be accompanying the allergic child in the trip in allergen avoidance on symptoms recognition and emergency medication should overcome some situations of social exclusion.

CONCLUDING REMARKS

Food allergy reactions commonly occur outside the home environment. Food allergies are now seen as a health risk and there is a growing interest from the general public, media and the commercial sector. Community exposure, traveling abroad and lack of information from health care providers are factors that place patients at greater risk of severe or fatal anaphylaxis. In the community, many stakeholders need to work together to reduce the risk of allergic reactions to foods and to manage any that occur.

The ability of the parents of children with food allergies to assess the risk and manage their child's condition is highly dependent on the parental knowledge, attitudes, support of family/friends/others including support organisations and beliefs of food allergy. School nurses and teachers play a key role in managing young students with food allergies. For older students self-management should be encouraged. Policies regarding food allergy management in schools range widely, and are often inadequate if not made in conjunction with an informed clinician.

Many retail catering facilities are poorly prepared to handle the advent of anaphylaxis and staff often have poor knowledge on preventive management of food allergy. Businesses such as restaurants and takeaways have no legal obligation to warn customers about potential allergen content. The need for more training for restaurant/cafeteria/fast-food/take-away staff and consumer caution on food allergen content and staff knowledge gaps remains high.

Communication patterns of within the general community may be hampered by legitimate everyday social considerations such as embarrassment, choice, spontaneity and discrimination. Increased food allergy knowledge among the general public is required, nevertheless the needs and rights of the non-allergic population should be taken into consideration as well. Policies should be structured around ethical principles of confidentiality and anonymity, fairness, avoiding stigmatization, and empowerment of patients.

However, implementing proper risk management strategies should be evidence based. The paucity of randomized–controlled studies on evaluation of effectiveness and cost-effectiveness of such interventions has so far restricted the grade of recommendations to the level of expert consensus (Box 6). As a consequence, the adoption of procedures has been limited to very few countries. The time has come to undertake efforts to address these issues in the community at- large worldwide (Box 7).

Expert Panel

We are grateful to the expert panel for providing expert feedback on the final draft of the paper: Magnus Borres (Department of Women’s and Children’s Health, Uppsala University, Uppsala, Sweden), Anna Bręborowicz (Department of Pathophysiology, Poznan University of Medical Sciences, Poznan, Poland), Chun-Han Chan (Food Allergy Branch, Chemical Services Division, Food Standards Agency, London, UK), M. Hazel Gowland (Anaphylaxis Campaign, Farnborough, UK), Matt Greenhawt (Department of Internal Medicine, Division of Allergy and Clinical Immunology, The University of Michigan Food Allergy Center, The University of Michigan Medical School, and the University of Michigan Health System, Ann Arbor, Michigan, USA), Ruchi Gupta (Northwestern University Feinberg School of Medicine, Chicago, Ill; Ann & Robert H. Lurie Children’s Hospital of Chicago, Chicago, Illinois, USA), Marcia Podestà (Food Allergy Italia).

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Authors’ contribution
Antonella Muraro, Chair of the EAACI Food Allergy and Anaphylaxis Guidelines Initiative, has steered and coordinated the publication. Ioana Agache and Andy Clark wrote the first draft of the manuscript. All authors participated in the revision of the manuscript including the discussion of the recommendations and gaps.

Conflicts of interest
Antonella Muraro has provided scientific advice for Meda. Graham Roberts has provided scientific advice for Danone and ALK-Abelló; Thermo Fisher and ALK-Abelló have provided consumables for his research activities. Jonathan O’B. Hourihane has received speaker fees from Mead Johnson, Nutricia, MSD, Pfizer, ALK-Abelló and Stallergenes; Thermo Fisher have provided consumables for his research activities. Luis Miguel Borrego has received honoraria for lectures from MSD. Sabine Schnadt has support for travel to EAACI congress from Peanut Council and Novartis. Ioana Agache, Jennette Higgs, Angel Mazon, Magnus Wickman, Maria Said, Davide Parmigiani, Andrew Clark, Cecmi Akdis, Berber Vlieg-Boerstra, Penny Jorgensen, Harmieke van Os-Medendorp and Aziz Sheikh have no conflict of interests in relation to this manuscript.

References

Box 6 Research gaps

<table>
<thead>
<tr>
<th>Gaps in the evidence</th>
<th>Plan to address</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidemiology of food-induced anaphylactic reactions in the community (incidence and risk assessment)</td>
<td>Disease registries and large epidemiological trials with a common methodology</td>
<td>High</td>
</tr>
<tr>
<td>Population thresholds for common food allergens and interaction with co-factors</td>
<td>Studies to estimate population thresholds and actions levels for common food allergens, including estimating the effect of co-factors (e.g. exercise) on the action levels</td>
<td>High</td>
</tr>
<tr>
<td>Objective measurement of interventions aimed to reduce in the community</td>
<td>Pragmatic (RCTs) to prevent food allergic reactions in the community including quality of life / anxiety score as outcome measure.</td>
<td>High</td>
</tr>
<tr>
<td>Comparison between various intervention methods for efficacy and cost-effectiveness</td>
<td>RCTs of various media (smartphone apps and websites) to implement/reinforce training packages for prevention and acute management of reactions. Especially useful for evaluation of specific target groups, such as teenagers/young adults and teachers.</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Trials of efficacy and cost-effectiveness of different models of school training implementation, e.g. web based school nurse training versus face-face.</td>
<td>High</td>
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<tr>
<td></td>
<td>Trials of efficacy and cost-effectiveness of different models to improve knowledge base of community food providers.</td>
<td>High</td>
</tr>
</tbody>
</table>
### Box 7  Families, healthcare professionals, schools, food outlets: implementation and audit

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Evidence level</th>
<th>Grade</th>
<th>Barriers to implementation</th>
<th>Facilitators to implementation</th>
<th>Audit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>THE INDIVIDUAL / FAMILY</strong></td>
<td></td>
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<tr>
<td>Implement allergen strategies recommended by the allergist, nurse and dietitian both within the home and the wider community</td>
<td>V</td>
<td>D</td>
<td>Lack of trained personnel to explain the indications</td>
<td>Education of the family as a whole, including caregivers through specific educational courses</td>
<td>% of families receiving proper advice</td>
</tr>
<tr>
<td>For children, inform the school/early-years settings of the allergy and provide them with a food allergy management plan from the allergist.</td>
<td>V</td>
<td>D</td>
<td>Lack of allergists Lack of time and adequate knowledge among primary care physicians Fear of stigma Lack of proper legislation implementing guidelines for school</td>
<td>Education and training of nurses and medical students Education on psychological issues and proper communication Implementation of specific legislation</td>
<td>% of patients with food allergy management plans at school</td>
</tr>
<tr>
<td>Keep regular follow up with the allergist and school nurse and dietitian and forward new copies of treatment plans to the school as they are updated</td>
<td>V</td>
<td>D</td>
<td>Lack of communication among stakeholders Lack of trained personnel Long waiting lists</td>
<td>Implementation of communication flow e.g. web based</td>
<td>% of school receiving updates directly</td>
</tr>
<tr>
<td>Monitor medication expiry dates and replace adrenaline auto-injectors as required</td>
<td>V</td>
<td>D</td>
<td>Lack of knowledge that adrenaline auto-injectors expire, availability and cost of auto-injectors</td>
<td>Alert systems as reminder, check at each physician’s visit</td>
<td>% of patient with adrenaline auto-injector</td>
</tr>
<tr>
<td><strong>THE ALLERGIST (ALLERGY SPECIALIST OR OTHER HEALTHCARE PROFESSIONAL WITH THE APPROPRIATE TRAINING AND COMPETENCY)</strong></td>
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<tr>
<td>Provide a comprehensive food allergy management plan incorporating the following features: diagnosis, risk assessment, allergen avoidance advice, provision and training in emergency medication, including adrenaline auto-injectors.</td>
<td>V</td>
<td>D</td>
<td>Lack of knowledge among healthcare professionals, lack of training</td>
<td>Education to primary care physicians, nurses, dietitians and medical students</td>
<td>% of patients receiving an adequate comprehensive consultation</td>
</tr>
<tr>
<td>Provide a written management plan incorporating relevant allergen avoidance advice and use of emergency medication. This should be passed to the school to form a basis for the personalized care plan (PCP).</td>
<td>V</td>
<td>D</td>
<td>Lack of trained personnel, lack of adequate communication with the school</td>
<td>Education to primary care physicians, nurses, dietitians and medical students</td>
<td>% of patients receiving management plans</td>
</tr>
<tr>
<td>Liaise with educational services (for children) to develop/maintain a comprehensive school allergy policy and individual PCPs.</td>
<td>V</td>
<td>D</td>
<td>Lack of time and resources</td>
<td>Compensation for time spent for educational activity</td>
<td>% of consultations to school</td>
</tr>
<tr>
<td>Recommendation</td>
<td>Evidence level</td>
<td>Grade</td>
<td>Barriers to implementation</td>
<td>Facilitators to implementation</td>
<td>Audit criteria</td>
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<td><strong>SCHOOLS: RECOMMENDATIONS</strong></td>
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<tr>
<td>The principal should develop a comprehensive school policy for allergy aware management and a staff member should be identified to coordinate allergy care and liaise with local allergy services.</td>
<td>IV</td>
<td>D</td>
<td>Lack of specific national guidelines for school Liability issues for school staff to be addressed</td>
<td>Implementing national guidelines for school</td>
<td>% of national countries with guidelines for school % of schools with management plans</td>
</tr>
<tr>
<td>The school should identify all children with food allergy in its care, and each should have a comprehensive PCP.</td>
<td>IV</td>
<td>D</td>
<td>Lack of specific national guidelines for school</td>
<td>Implementing national guidelines for school</td>
<td>% of national countries with guidelines for school % of children correctly identified</td>
</tr>
<tr>
<td>The school should engage with local allergy specialists to provide input into PCPs and staff training.</td>
<td>IV</td>
<td>D</td>
<td>Lack of specific national guidelines for school</td>
<td>Implementing national guidelines for school</td>
<td>% of national countries with guidelines for school % of school staff trained</td>
</tr>
<tr>
<td>The school should store emergency medication for each child as recommended by the allergist. Medication should be readily available.</td>
<td>IV</td>
<td>D</td>
<td>Lack of specific national guidelines for school</td>
<td>Implementing national guidelines for school</td>
<td>% of staff aware of the medication storage and expiry date</td>
</tr>
<tr>
<td>Allergy awareness should be applied to cooking and handling of food anywhere in the school</td>
<td>IV</td>
<td>D</td>
<td>Lack of specific national guidelines for school Liability issues for school staff to be addressed</td>
<td>Implementing national guidelines Implementing procedures</td>
<td>% of school with proper procedures</td>
</tr>
<tr>
<td>The scope of the comprehensive school policy should extend to school trips, exchanges and excursions</td>
<td>IV</td>
<td>D</td>
<td>Lack of specific national guidelines for school Liability issues for school staff to be addressed</td>
<td>Implementing national guidelines Implementing procedures</td>
<td>% of school with proper procedures</td>
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<td><strong>SUPPLIERS AND PROVIDERS OF NON-PACKAGED FOODS</strong></td>
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<tr>
<td>Seek training and obtain competency in serving customers who have food allergy</td>
<td>IV</td>
<td>D</td>
<td>Lack of awareness, knowledge and training, lack of legislation</td>
<td>Educational courses</td>
<td>% of staff with adequate knowledge</td>
</tr>
<tr>
<td>Implement policy and procedures to reduce cross-contamination</td>
<td>IV</td>
<td>D</td>
<td>Lack of awareness, knowledge and training, lack of legislation, lack of funding for educational activities</td>
<td>Educational courses on national basis funded by the Government or charities Implementation of policies and procedures</td>
<td>% of policies and procedures developed and implemented</td>
</tr>
<tr>
<td>Provide information to customers about food allergen content or possible cross contamination</td>
<td>IV</td>
<td>D</td>
<td>Lack of awareness, knowledge and training, lack of legislation</td>
<td>Educational courses on national basis funded by the Government or charities Implementation of policies and procedures</td>
<td>% of customers receiving proper management</td>
</tr>
</tbody>
</table>


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6.1 PROTECTING CONSUMERS WITH FOOD ALLERGIES

EAACI GUIDELINES

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* Joint first author
Individuals suffering from IgE-mediated food allergy usually have to practice life-long food allergen avoidance. This chapter aims to provide an overview of recent evidence-based recommendations for allergen risk assessment and management in the food industry and discusses unmet needs and expectations of the consumer with food allergies in that context. There is a general duty of care on the food industry and obligations in European Union legislation to reduce and manage the presence of allergens alongside other food hazards. Current evidence enables quantification of allergen reference doses which can be used to set up reliable food safety management plans for some foods. However, further work is required to include a wider variety of foods and to understand the impact of the food matrix as well as additional factors which affect the progression and severity of symptoms as a function of dose. Major concerns have been raised by patients/carers and patient groups about the perceived over-use of precautionary 'may contain' labelling to address the issue of the unintended presence of allergens; these therefore need to be reconsidered. New and improved allergen detection methods should be evaluated for their application in food production. There is an urgent requirement for effective communication between healthcare professionals, patient organizations, food industry representatives and regulators to develop a better approach to protecting consumers with food allergies.
Protecting consumers with food allergies

BACKGROUND

IgE-mediated food allergy is an important chronic disease manifested by a range of symptoms which can sometimes become life-threatening (1, 2). In the absence of a cure, individuals with food allergy usually have to practice lifelong food allergen avoidance. Those at risk of severe allergic reactions must be equipped with rescue medication in case they accidentally consume or have contact with the culprit food. As most common allergenic foods provide valuable nutrition and dietary variety, it is neither practical nor desirable to eliminate these from all food products. Therefore, allergens are ubiquitous elements in food manufacturing environments. In order to support consumers with food allergy in avoiding food allergens, European Union (EU) food legislation requires the labelling of allergenic food components which are used as ingredients (3). It also imposes a general duty of care on the food industry to reduce and manage, control and communicate the presence of allergens alongside other food hazards (Box 1). This requires allergenic ingredients to be managed rather than eliminated completely from the food supply (4). However, the majority of foods are processed on shared equipment and so-called allergen cross-contact may lead to the unintended presence of allergens. To date, the frequency and extent of cross-contact in commercial food items is generally unknown. As a consequence, precautionary labelling, such as “may contain...” is frequently used. This is partly for product liability reasons but also to provide additional consumer safety information, even though application of the precautionary labelling may not be evidence-based. In addition, important gaps in knowledge regarding the allergen risk management of manufactured food

Box 1 Key terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allergen</td>
<td>Any substance to which IgE may react causing triggering of effectors via FcERI-crosslinking; usually a protein. For allergen management this term usually refers to the food.</td>
</tr>
<tr>
<td>Clinical threshold doses</td>
<td>The lowest dose of an allergenic food to elicit an objective allergic reaction in an individual during a food challenge test.</td>
</tr>
<tr>
<td>Co-factors</td>
<td>Patient related circumstances that may modify allergic reactions to be more severe. They are known also as augmentation factors.</td>
</tr>
<tr>
<td>Cross-contact / cross-contamination</td>
<td>Unintentional transfer of an allergenic food/ingredient into another food even despite existing GMP. Applies for both, prepacked and whole foods.</td>
</tr>
<tr>
<td>Food</td>
<td>Any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of “food” but does not include cosmetics or tobacco or substances used only as drugs (Codex Alimentarius).</td>
</tr>
<tr>
<td>Food label</td>
<td>Any tag, brand, mark, pictorial or other descriptive matter, written, printed or stencilled on the packaging or container of food.</td>
</tr>
<tr>
<td>Reference dose</td>
<td>The amount of the allergenic food (mg protein) below which adverse reactions are unlikely.</td>
</tr>
<tr>
<td>Risk assessment</td>
<td>A scientifically based process consisting of four steps: hazard identification, hazard characterization, exposure assessment and risk characterization (5).</td>
</tr>
<tr>
<td>Risk communication</td>
<td>The interactive exchange of information and opinions throughout the risk analysis process with regard to hazards and risks, related factors and perceptions among risk assessors, managers, consumers, the academic community and other interested parties (5).</td>
</tr>
<tr>
<td>Risk management for food safety</td>
<td>A network of inter-related elements ensuring that food does not cause adverse human health effects. These elements include programmes, plans, policies, processes, methods, controls, responsibilities, documents, records and resources (6).</td>
</tr>
</tbody>
</table>
remain. Proper, improved and novel tools that enable food industry to develop and implement effective allergen management strategies are urgently required. In parallel, efficient training strategies for food manufacturing and catering companies have to be developed. Last, but not least, adequate support for consumers with food allergy needs to be developed. It is necessary to understand consumer attitudes to allergens in foods, and to appreciate who is avoiding which foods and why. This decision depends on each individual’s potential severity of symptoms, their age, their understanding and social circumstances. For effective and personalized food allergen avoidance, providing the essential information is a key element, as well as adequate training of the patients to read and interpret the labels of pre-packed and non pre-packed foods as well as talking to food suppliers for further information.

METHODS
Clarifying the scope and purpose of this document

The process began in January 2012 with a meeting to discuss the overall approach to guideline development. This included detailed discussions on the main aims of the guidelines, the target conditions, agreeing the intended end-user for the recommendations, agreeing the intended end-user group, and ensuring adequate professional and lay representation in the guidelines development process.

Ensuring appropriate stakeholder involvement

Participants represented different disciplinary and clinical backgrounds, including medical tertiary, secondary and primary care (Aziz Sheikh) and patient groups (Sabine Schnadt (Germany), Hazel Gowland (UK)).

Formulating recommendations

This chapter aims to provide an overview of recent evidence-based recommendations for allergen risk assessment and management in the food industry and discusses unmet needs and expectations of the food allergic consumer in that context. Key issues are summarised with regard to food allergens and the food allergic consumer, including the perceived excessive use of precautionary labelling, (7) the lack of common standards for risk assessment, the suboptimal analytical methodology and the communication between consumers at risk, food manufacturers and regulators to establish a common understanding of the risk. In order to build on the current status quo and improve experiences and outcomes for patients/carers, there is a need to agree common standards and develop clear risk-based use of precautionary labelling, which provide a valid and reliable communication of risk, and support the issuing of clear allergen management advice for use in the food manufacturing area. The target audience for this review comprises patients' organizations, regulators, allergists and healthcare professionals as well as food manufacturers, retailers and caterers. The following recommendations are the result of expert opinion consensus following previous systematic reviews of literature on epidemiology, diagnosis and management of food allergy and anaphylaxis (8-11) (see Chapters 1.1, 1.2, 1.3, 4.1, 4.2) and extensive narrative review of the relevant literature. They result also from consultations with all stakeholders involved in management of food allergy and anaphylaxis including primary care physicians and patient organizations. The most important goals are summarized in Box 2.

Box 2 Major goals

- To identify best practice for allergen risk assessment in food manufacturing and catering.
- To examine the evidence-base that underpins allergen management plans and risk communication strategies, including application of precautionary labelling.
- To examine education / training strategies for food manufacturing and catering companies.
- To identify relevant analytical tools and enforcement practices of regulatory authorities.
- To identify best education and training strategies for food allergic consumers to assess the information presented on food labels relevant for their allergic condition.
Editorial independence and managing conflict of interests

The production of these guidelines was funded and supported by EAACI. The funders did not have any influence on the guideline production process, its contents or on the decision to publish. All members of the Community Task Force completed conflicts of interest statements and these were taken into account by the Community Task Force chair as recommendations were formulated.

Updating the guidelines

We plan to update this document in 2017 unless there are important advances before then.

RISK ASSESSMENT: TOWARDS EVIDENCE-BASED REFERENCE DOSES

Within the last two decades, great efforts have been undertaken in assessing the risk arising from allergenic ingredients in food products for consumers with food allergies. Due to the fact that the range of reactivity to allergens is very wide (up to 6 orders of magnitude, calculated from controlled food challenge studies; (12)) it is evident that the development of an evidence-based risk assessment for food allergens is a challenging task. The overall uncertainty of the risk due to even very small residual amounts of allergen and the consequent effect for a consumer who is highly sensitive, with or without co-factors, has led to the introduction of precautionary labelling (13).

Recently, the Australian Voluntary Incidental Trace Allergen Labelling (VITAL) initiative and the ILSI Europe Food Allergy Task Force reviewed data sets from previous food challenges with regard to reactions to low doses of different allergenic foods and performed a probabilistic risk assessment approach (13-15). The eliciting dose for inducing an allergic reaction in 1% of the specific allergic population (ED01) was estimated for peanut as 0.2 mg protein, i.e. 1% of the peanut allergic individuals would react to a dose of 0.2 mg peanut protein (Table 1). Other ED01 levels have been developed for cow’s milk, hen’s egg, and hazelnut (13). ED05 values have been identified for wheat, mustard, lupin, cashew, sesame seed, shrimp and fish (14, 15). So far, doses for celery and tree nuts, other than hazelnut and cashew, are lacking (15). Depending on the allergic food, doses ranged from 0.03 mg (egg) to 10 mg (shrimp). The availability of these reference doses provides the foundations for an evidence-based approach for redesigning efficient risk assessment applicable to food production.

The VITAL approach is designed for situations where the unintended allergen is distributed evenly (homogenously) in the product. In cases where allergens are present in a particulate form (e.g. nut pieces, sesame seeds) and not evenly distributed, this approach is not applicable (16). For these cases, the use of precautionary labelling is the only current option when the risk is unacceptable.

**Table 1 Suggested reference doses for allergenic foods**

<table>
<thead>
<tr>
<th>Food</th>
<th>Reference dose (mg protein)</th>
<th>Required analytical sensitivity**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanut</td>
<td>0.2</td>
<td>4</td>
</tr>
<tr>
<td>Cow’s milk</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Egg</td>
<td>0.03</td>
<td>0.6</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Soy</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Wheat</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Cashew</td>
<td>2.0</td>
<td>40</td>
</tr>
<tr>
<td>Mustard</td>
<td>0.05</td>
<td>1</td>
</tr>
<tr>
<td>Lupin</td>
<td>4.0</td>
<td>80</td>
</tr>
<tr>
<td>Sesame seed</td>
<td>0.2</td>
<td>4</td>
</tr>
<tr>
<td>Shrimp</td>
<td>10.0</td>
<td>200</td>
</tr>
<tr>
<td>Fish†</td>
<td>0.1</td>
<td>2</td>
</tr>
</tbody>
</table>

* (modified from Taylor et al. (15); Allen et al. (13) and Alvarez and Boye (43), the respective serving size and the detection limit of cross-contamination as assessed by ELISA.
** Required analytical sensitivity (mg/kg, ppm) of a method to detect a protein reference dose in a defined amount of a serving size, e.g. 50 gram.
† eliciting doses for 1% of food allergic population (ED01).
‡ eliciting doses for 5% of food allergic population (ED05).
# provisional data

ALLERGEN MANAGEMENT: PART OF EXISTING FOOD SAFETY MANAGEMENT

The need to set standards and procedures for
allergen management and to incorporate them into existing overall food safety assurance strategies in compliance with good manufacturing practices (GMP) is well recognized by the food industry and includes a management plan to identify, prevent and control food safety hazards (HACCP – hazard analysis critical control point).

Recently, FoodDrinkEurope published a guidance document (6) for food producers, to harmonize and disseminate robust and evidence-based information on good practice in risk management of allergenic foods. This guidance document drew on various national guidance documents, as well as research results from the European Commission funded research project EuroPrevall, recommendations from the MoniQA EU Network of Excellence, and from ILSI International Life Sciences Institute, Europe. Key elements of allergen risk management included: correct training of the personnel involved in the production procedures; complete information of raw materials; adequate production facilities; state-of-the-art manufacturing; provision of accurate and reliable/trustworthy information for the consumer at risk, product development and parallel updates of relevant information and continuous documentation (6). Correct cleaning procedures for the processing plant to avoid cross contamination are particularly critical.

**Labelling**

**Food allergen labelling: Issues relating to the deliberate use of allergenic ingredients**

Within the current EU legislation ((European Directive 2007/68/EC (17) amending Directive 2000/13/EC (18) the labelling of 13 allergenic foods (or food groups) and derived products thereof, as specified in annex IIIa of directive 2007/68/EC, is mandatory when used as ingredients for pre-packed foods, regardless of the concentration of the potentially allergenic ingredient. The 13 allergenic foods (or food groups) include the most important foods (Table 2) that cause IgE mediated and non IgE mediated allergies, coeliac disease due to reactivity to gluten. Sulphur dioxide and sulphites, also listed in this Directive, cause intolerances and are therefore not further discussed in this review.

Certain products derived from the foods on the list may be exempted from the labelling requirement if they can be assessed and found to be non-allergenic. For example wheat based glucose syrups, including dextrose or maltose, do not require labelling. Other exceptions are fish gelatin used as a carrier for vitamins or carotenoids, fully refined soybean oil, and alcoholic distillates derived from nuts.

Regulation 1169/2011(19) on the provision of food information (FIR) to consumers, that will be effective from 13 December 2014, will replace the existing labelling directive, including its provisions for allergens. The FIR provides detailed information on how to present allergen information and clearly states the nature of the allergy-inducing substance or product on the respective labels and extends allergen labelling to non-prepackaged foods. A systematic re-examination and potential update of the allergen list by the EU-Commission is also foreseen (19). Since this EU-legislation is enforced by the national legislation of its member states (19), differences across countries regarding the type of labelling are likely, and strategies to harmonise these activities are needed as examples have shown in the past. For non-prepacked food products that lack an ingredient list, provision of allergen information is also required at the point of sale after the end of the regulatory transition period in December 2014. Also the information on allergenic ingredients is mandatory. However, the means through which information about the presence of these allergenic compounds is to be made available to consumers has been derogated to the EU member states. Issues remain regarding the inadvertent presence of so-called “cross-contact” allergens which are not covered by Directive 1169/2011 and may therefore result in the ongoing application and over-use of precautionary labelling statements, such as “may contain”, or “trace amounts of” (see below).

Similar activities on allergen labelling legislation have been performed in other parts of the world and are summarised in Table 2. The EU list is currently the most comprehensive one and was followed by other countries such as Switzerland, Argentina and Ukraine (20). In contrast, Japan only requires mandatory labelling for wheat, buckwheat, egg, milk, peanut and crustaceans. However, an additional 19 foods are listed for “recommended labelling”. The allergenic foods cited in almost all labelling regulations are milk, egg, gluten containing cereals, crustaceae, peanuts and tree nuts. Others, such as mustard, mollusc, lupin and buckwheat seem to be restricted to certain geographic areas, possibly...
Protecting consumers with food allergies

Precautionary labeling: impact on food avoidance strategies of consumers at risk

In cases of unintended presence of allergens, voluntary allergen labelling information is applied by the food manufacturer in order to inform and protect consumers with allergies, and is guided by Article 36. However, precautionary labelling indicating the unintentional presence of allergens should only be used when there is a significant probability of allergen cross contamination representing an unacceptable risk to the allergic consumer. However, detailed guidance on quantitative risk assessment remains to be developed and needs to be underpinned by a transparent evidence base. A recent study from Crotty and Taylor (21) analysed precautionary labelling for milk in 100 food products.

Table 2 Labelling of allergenic foods according to regulatory frameworks

<table>
<thead>
<tr>
<th></th>
<th>Codex¹</th>
<th>European Union²</th>
<th>Australia/New Zealand</th>
<th>Canada</th>
<th>China</th>
<th>Hong Kong</th>
<th>Japan</th>
<th>Korea</th>
<th>Mexico</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat / cereals³</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X⁴</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Eggs</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Milk</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Peanut</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fish</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X⁶</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Soy</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tree nuts</td>
<td>X</td>
<td>X⁹</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sesame</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shellfish/ mollusks</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mustard</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Celery</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lupine</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>X⁷</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X⁸</td>
</tr>
</tbody>
</table>

Table modified from Gendel S. Reg. Toxicol and Pharmacol. 2012; (20)

¹. The following countries use CODEX regulations: Barbados, Chile, Papua Neuginea, Philippines, St. Vincent and The Grenadines.
². Argentina, Switzerland and Ukraine also use The European legislation.
³. Cereals containing gluten
⁴. Wheat and buckwheat
⁵. Shrimp and crab listed under crustaceans
⁶. Mackerel as the only fish listed
⁷. Foods recommended for labelling: abalone, squid, salmon roe, salmon, mackerel, chicken, beef, pork, gelatin, matsutake mushroom, walnut, orange, kiwifruit, soybean, banana, peach, apple, kiwifruit, yam.
⁸. “Other” includes pork, peach, tomatoe.
⁹. European Union listed the following tree nuts: almonds, brazil nuts, cashews, hazelnuts, macadamia nuts, pecans, pistachio nuts and walnuts.
¹⁰. Canada listed the following tree nuts: almonds, brazil nuts, cashews, hazelnuts, macadamia nuts, pecans, pine nuts, pistachio nuts and walnuts

reflecting the different dietary habits and thus risk of exposure.
Forty percent of products labelled with “may contain milk ingredients” had detectable milk residues, with a wide range of concentrations (3.4 - 15000ppm, (21)). In products with labels indicating “shared equipment” or “shared facility” the frequency of detected milk ingredients was lower. Finally 40% of products listing milk as a minor ingredient did not have any detectable milk. Comparing different food matrices, dark chocolate was identified as a high risk product for milk allergic consumers. Another study from Ford et al. (22) compared food products with precautionary labelling for 3 allergen sources, peanut, milk and egg. Detectable amounts of allergenic foods were identified in 5.3% of products with precautionary labels and in 1.9% of products without precautionary labelling. Therefore, the authors conclude that the avoidance of product with advisory statements should be recommended for the consumer at risk, even if the detectable amounts of culprit allergen source may be rather low (22). A recent Irish study on peanut containing foods with advisory labels detected low levels of peanut in only 2 out of 38 products (23). Based on their data the authors discussed whether there is a sufficient risk warranting the use of advisory labelling. However, they also concluded that for the sake of patients with peanut allergy and their avoidance strategies, advisory nut statements should still be recommended.

Recent studies have highlighted the fact, that due to the excessive use of precautionary labelling, the perception, opinions and behaviour of patients with food allergies have changed (24-26). In general, they are rather complacent about this type of labelling (27). However, they also assume that different statements reflect different levels of risk with statements such as “shared facility” implying a lower risk than “may contain”, for example (27).

**TOOLS FOR EFFECTIVE ALLERGEN RISK MANAGEMENT**

Allergen risk assessment is an integral part of allergen risk management and estimates the impact of a health hazard as a function of dose and exposure (Figure 1 (14)). As a consequence, the definition of an acceptable versus unacceptable risk needs to be defined and agreed upon. Therefore, an effective allergen risk management strategy relies on the information of threshold levels for clinical reactivity. While threshold levels for toxic substances are generally available, threshold levels for allergens have, until recently, remained elusive (28). It is known that allergic individuals can respond to a very wide range of doses, and generally accepted levels are not yet agreed. Despite the individual differences in threshold doses, Crevel et al. have suggested...
identifying an “eliciting dose” for a specified fraction of the allergic population, for instance 5 or 10% (ED05 or ED10 (13-15, 29)) as the amount of an allergen, known to produce a reaction in defined proportion of the allergic population. This parameter could be used for the concept of “protection of the vast majority” and representing the basis for food safety objectives. It also acknowledges the fact that complete protection of the allergic population, absolute safety (‘zero risk’), is not possible (30). Convincing data on threshold levels have been generated for 11 allergenic food sources, for other allergenic food sources lack these data (see also section above (15)). Within EuroPrevall great efforts were undertaken, to develop harmonized challenge protocols, apply standardized challenge meals to assess threshold levels for the most important food allergen sources in a multicentre study, and forthcoming results are expected to provide necessary information on threshold doses for both the food industry and regulators (31, 32). It should be recognized however that threshold levels are determined under optimal experimental conditions and little is known about changes in individuals’ threshold due to co-factors such as infectious diseases, drug intake (e.g. non-steroidal anti-inflammatory drugs (NSAIDs) are known to increase intestinal permeability and antacids to interfere with the physiological breakdown of food proteins), alcohol, stress and exercise.

An integral part of implementation of allergen risk management in food manufacturing and retailing is the ability to validate and then verify, for example, that cleaning practices are effective and that finished food products comply with the quality criteria laid out in allergen management plans. This applies with even more force when a claim, as in “free-from” foods, is made. Thus a suite of analytical methods are required ranging from rapid and easy-to-use qualitative and semi-quantitative methods that can be applied in a food manufacturing environment to more rigorous quantitative methods. In general, analytical methods that target the hazard are preferable, and hence those able to determine the presence of the allergenic proteins are considered to be the best available methodology. However, most use a methodology based on the detection of indicative proteins, peptides or nucleic acids rather than the actual allergen. Clearly, the detection of peptides or proteins is more closely related to the presence of allergenic proteins. Independently, various studies have demonstrated the successful application of nucleic acid-based methods, such as PCR (polymerase chain reaction), which correlates well with protein-based methods (33).

The detection of specific proteins and even allergens by specific antibodies using ELISA techniques is most frequently applied (34-36). These highly sensitive methods are widely used, and detect cross-contaminants in foods at or below the ppm (mg allergen per kg food) level (Table 1).

Recently, mass spectrometry (MS) approaches have been developed to detect peptide and proteins even in complex food matrices with high sensitivity (37, 38). In the case of hazelnut detection, a recent project demonstrated comparability between the available techniques, ELISA, PCR, and MS (39). Further development of such orthogonal methodology is needed before routine application is possible. Analytical methods do not detect absolute amounts of allergen doses but quantify the concentration of an allergenic protein or food (e.g. peanut) in a reference size such as a serving size (e.g. 50 gram) of the composed food (e.g. chocolate). Depending on: a) the reference dose for the allergenic food that is summarized in Table 1; and b) the serving size, the methods need to be sufficiently sensitive to reliably detect or quantify the respective concentration. The limit of detection of the methods needs to be below this concentration (Table 1).

When performing analytical methods for allergen detection in foods, the impact of food processing and the food matrix on the individual allergens should be taken into account. Processing and matrix factors may induce unpredictable effects, making analytical results difficult to interpret. Allergenic food proteins are part of the diet and interact with the respective food matrix. Furthermore, these proteins may undergo changes due to food processing treatments which in turn affect their allergenicity. Data on potential changes in allergenicity are thus relevant for refined allergen risk assessment in food production and detection assays should be extended with “processed” allergenic molecules. The influence of processing on allergenicity should be assessed in clinical food challenge studies. Only limited data from such studies in humans are currently available (40). These issues are further confounded by the lack of agreed reference doses for allergens in foods, making it impossible to set effective parameters for optimal analytical performance, such as limit of quantification.
Furthermore, the lack of reference materials, in particular for naturally-incurred materials, for allergen detection has meant there is a lack of consensus regarding reporting units for allergens, and also that it is not currently possible to undertake the necessary inter-laboratory trials to select the best-practice methodology. The development of such reference materials will also need to ensure that the allergenic molecules are present in a relevant form. As proof of concept, a recent multi-laboratory trial used a dessert matrix already validated for clinical use which was tested as a quality control material for allergen analysis, in order to compare a range of commercially available immunoassays for egg and milk content (41).

Communication and training

Consumers purchase products on the basis of trust, experience and recommendation, expecting that they are for safe use, unless specific information is given on the labels. The food industry is increasingly recognizing its role in implementing preventive measures to protect the allergic consumer from having reactions through accidental consumption of their problem food. However, it is also evident that key knowledge and skills are essential to support them in undertaking effective food avoidance. In this context, the indiscriminate use of precautionary labelling has led to loss of confidence from the allergic consumer in this risk communication tool (12). Therefore appropriate communication strategies are needed. For example, communicating that reference doses – if available – are associated with a certain risk of reaction. This in turn requires adequate training of the patients with allergies to obtain the relevant information on the food product and from the food suppliers. Therefore the key element is the close cooperation and effective communication between patient organizations, food industry representatives and regulators. Moreover, adequate training of individuals who have contact with customers – from helplines, to those in the retailing and catering sectors – is of great importance. This also extends to those involved in caring for individuals with food allergies in the extended community including personnel in day care centres, nurseries and teachers. This is needed to increase awareness about food allergies and thus reduce the risk of accidental exposure of food allergens as well as prompt action in the event of such exposure (see also food allergy guidelines, Chapter 1.5).

Box 3. Gaps in the evidence

- Need for harmonization in labeling activities with regard to layout, terminology.
- Need for generally agreed reference doses for most important food allergen sources.
- Need for certified reference material and standardized detection assays.
- Definition of tolerable risk level in food allergy.
- Best practices to train and support the food allergic consumer and to select optimal communication for both consumer at risk and third party.

Gaps in the evidence

There is an urgent need for agreement on threshold levels for individual food allergens sources based on double-blind, placebo-controlled food challenges (DBPCFC) studies, as well as generation of further challenge data for allergens for which currently available data are insufficient (Box 3). In this context, the VITAL 2.0 system developed in Australia has generated much interest. For allergen detection assays standardized and certified reference materials are still lacking. Novel analytical methods and their applicability in reliable allergen detection in various food matrices should be investigated. Novel insights into food matrices, food processing and their impact on the allergenicity of foods should also be incorporated into allergen risk management once a sound knowledge base has been developed. Although important, limited data are available on the impact of food avoidance on the quality of life and the related costs to allergic consumers. (42)

Summary and recommendations

It is now well recognized that protecting the allergic consumer from unintended exposure to allergenic food is a shared responsibility, in which each stakeholder must play their part. EU legislation on allergen labelling is in place and is implemented and enforced through the respective national laws. As a result, differences in the layout, terminology used, and practices arise. To harmonize labelling issues, industry has started efforts for disseminating best practices among food producers. Labelling of non-packaged (or indeed
Protecting consumers with food allergies

(Prepackaged) foods is not yet available in all countries, although the relevant legislation will apply in the near future. In general, precautionary labelling should be avoided whenever possible, since every additional ‘may contain’ warning diminishes the impact of those already used, thereby increasing the risk of unnecessary risk taking and hence exposure. As a matter of principle, it should not be applied without a thorough risk management plan based on a transparent evidence base. Adequate training of the personnel working in the food manufacture, catering, nurseries and schools is critical. Lastly access to relevant information on food allergy is an essential resource to improve the quality of life of the allergic consumer.

The food industry has started to integrate allergen management in existing food safety management procedures. However, there is an urgent need for certified reference materials. It is of concern that agreement around management threshold levels for key food allergen sources is still lacking. Implementation of such thresholds could ensure a high degree of protection while avoiding excessive food choice restriction for allergic consumers. Close cooperation is needed between regulators, food industry representatives and consumer organizations in order to define tolerable risk levels in food allergy.

Acknowledgements

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Conflict of interests

Antonella Muraro has provided scientific advice for Meda. Karin Hoffmann-Sommergruber has received honoraria from Thermo Fisher and Milupa. Lars Poulsen has provided scientific advice to Nvozymes and has received funding for research from ALK-Abelló, Anergis, Biomay, Stallergenes. Graham Roberts has provided scientific advice for Danone and ALK-Abelló; Thermo Fisher and ALK-Abelló have provided consumables for his research activities. Sabine Schnadt has received support for travel to EAACI congress from Peanut Council and Novartis. Aziz Sheikh has received funding for coordinating guidelines production, and generating the systematic reviews from EAACI. He has provided scientific advice to ALK-Abelló, Meda, Lincoln Medical, Thermo Fisher, Pfizer and Stallergenes; he is on the Anaphylaxis Campaign UK’s Scientific Committee, World Allergy Organization’s Anaphylaxis Special Committee, UK Resuscitation Council’s Anaphylaxis Committee and the BSACI’s Standard of Care Committee. Cezmi A Akdis has received research grants from Allergopharma, Stallergenes, Actelion, and Novartis. Besides, Cezmi A Akdis was President (2011–2013), Past President (2013–2015), and ExCom member in EAACI, which has received financial support from several relevant business entities. Ronald van Ree has provided scientific advice for HAL Allergy, Stallergenes, BIAL, Ventria Bioscience, Pharming; he has provided contract research services to HAL Allergy, Stallergenes and Ventria Bioscience and has received consumables from Thermo Fischer. Hazel Gowland is a researcher on Food Standards Agency funded projects and unpaid adviser to other FSA funded studies. Clare Mills has received funding from the European Food Safety Authority, sits on the UK Food Standards’ Agency’s Advisory Committee and is a cofounder of the start-up company Reacta Biotech Ltd. Nikos Papadopoulos is currently EAACI President (2013–2015) and has provided consulting for several relevant business entities. Thomas Holzhauser had consultant arrangements with Institut für Produkt Qualität, Berlin and scientific consultant arrangements with Monsanto Company. Stefan Vieths has no conflicts in relation to this document.

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SUMMARY AND FUTURE PERSPECTIVES

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The EAACI Food Allergy and Anaphylaxis Guidelines Group has worked over the last 2 years to generate a comprehensive set of guidelines. In this unprecedented project, the evidence base for food allergy and anaphylaxis has been systematically reviewed with the results being used to generate a comprehensive collection of 6 guidelines to inform the management of patients. The guidelines group consisted of over 70 individuals and was truly pan European and multidisciplinary with representation from primary care, secondary and tertiary care, health professionals including clinicians, nurse, and dieticians and psychologists as well as food scientists, patient group representatives and regulators. The guidelines group has worked within the context of the EAACI Food Allergy and Anaphylaxis Campaign which has sought to raise the profile of food allergy and anaphylaxis in Europe, to advocate for better care for patients and to improve the education of health professionals and the public.

The systematic reviews of the epidemiology of food allergies (Chapters 1.1, 1.2) summarize the burden of food allergy in European children, adolescents and adults. While the point prevalence of self-reported food allergy was found to be around 6%, the prevalence of food challenge proven food allergy was under 1%. This still though represents around 7.5 millions of affected individuals across Europe, with a large proportion of children. The key food allergens in Europe are cow’s milk, egg, wheat, peanut, tree nut, and fish and shell fish. The risk factors for food allergy frequently differ between studies. This may be due to local population differences but is more likely to be due to differences in study design. It is important that future studies adopt a uniform design with food challenges being used to make a gold standard diagnosis of food allergy. This will enable data from future studies to meta-analyzed in order to improve our ability to understand the pathogenesis of food allergy. Additionally, further epidemiological data is required from eastern and southern Europe, as they are very poorly represented in the current literature, to determine whether the burden of food allergy is similar across the whole of Europe.

There are now considerable data in the literature characterizing the performance of skin prick testing and specific IgE testing for food allergy (Chapter 1.3). Both skin prick testing and specific IgE testing have good sensitivity but relatively poor specificity for diagnosing food allergy. This means that they are good for ruling out food allergy but not so good for ruling the diagnosis in. However, most of the studies were very small with high risk of bias and there was a lack of head to head comparisons of skin prick testing and specific IgE testing. Additionally there was relatively little real life diagnostic data focused on component testing. These should be the focus of future studies.

Chapter 1.4 focused on the management of food allergy. This whole area is characterized by a lack of evidence, both for the acute management of non-life threatening allergic reactions and longer term management. This makes developing evidence based recommendations difficult. The EAACI food allergy guidelines (Chapter 1.5) covers history taking, determination of sensitisation to food, elimination diets, oral food challenges and the acute and long term management of food allergy. Apart from for skin prick testing, specific IgE testing and the use of hypoallergenic formulae, there is no high level evidence to guide management. Therefore many recommendations rely on extrapolations from other data or expert opinion. Of the many evidence gaps, high priority ones include: better approaches to identify patients at risk of developing severe reactions, evidence on the efficacy of modified food allergens (e.g. baked milk or egg) to accelerate the development of tolerance; evidence on the efficacy of oral induction of tolerance (OIT) for common food allergens; and better data on the role of monoclonal anti-IgE for managing food allergy with or without the concurrent use of OIT.

The current lack of a routine curative therapy for food allergy, emphasizes the need to develop effective preventive strategies. Chapter 2.1 summarizes the available data on the prevention of food allergy in a systematic review. The literature is difficult to interpret for many reasons: challenge based outcomes are rarely used resulting in the likely over diagnosis of food allergy; IgE sensitization status is often not taken into account avoiding consideration of the existence of multiple food allergy phenotypes; randomization to breast feeding, as a factor that is likely to be critical in the development of food allergy, is not ethical. Future studies need to be better designed. Therefore, only limited conclusions can be drawn from the data: a special diet is not required in pregnancy nor with lactation; infants should be exclusively breast fed for 4-6 months; if a high risk infant needs a formula feed, a proven hypoallergenic formula should be used; and complementary foods should be introduced from 4
Summary and future perspectives

months according to local weaning practices. Of the many evidence gaps in this area, perhaps the greatest priority for further data is on the effect of timing of weaning on the development of food allergy and whether concurrent breast feeding modifies the impact. Given the overload of food allergy on life, it is important to understand the quality of life of individuals with food allergy. The systematic review of the literature in Chapter 3.1 identified seven validated food allergy-specific, health-related quality of life questionnaires for children, adolescents, adults and parents. These can be used to quantify quality of life and the impact of interventions. Further work though is required to generate minimal important differences for these questionnaires to help interpret results. These questionnaires also need to be validated in a wider range of European countries. Recommendations for the development and use of quality of life questionnaires are made in Chapter 3.2.

Food allergy is the commonest cause of anaphylaxis. The systematic review of the literature in Chapter 4.1 found an incidence rate ranging from 1.5 to 7.9 per 100000 person-years. This broad range is likely to reflect both differing definitions of anaphylaxis and variation in different populations due to genetic or environmental factors. Better linkage of health data bases across primary and secondary sectors would facilitate better data collection and understanding of the epidemiology of anaphylaxis. The second systematic review focused on the management of anaphylaxis (Chapter 4.2). The lack of studies evaluating acute interventions in anaphylaxis is notable making it difficult to generate evidence based recommendations. The best data are for the pharmacokinetics of adrenaline, but not during an episode of anaphylaxis, and for venom immunotherapy as a means of preventing future severe reactions. The EAACI anaphylaxis guidelines (Chapter 4.3) stress adrenaline as the first intervention in anaphylaxis to tackle the under and delayed use of adrenaline. A full allergy assessment, the development of an individualized management plan and training are emphasized, although the evidence base for these is poor. Given the burden associated with anaphylaxis, this is an obvious priority area for further research studies. Key priorities would be better diagnostic criteria for emergency department staff to facilitate early identification of anaphylaxis; optimal dose and dosing interval for patients experiencing anaphylaxis; investigation of the role of sublingual adrenaline as an adjunct to intramuscular administration; understanding which components are required for an optimal individualize management plan; and assessment of the best approach to training patients and carers. Most allergic reactions to food occur in the community, this should therefore be the focus of strategies to prevent future reactions and procedures need to be in place to manage any reactions that do occur (Chapter 5.1). Schools are an important component and policies need to be in place to assist teachers and other staff. Healthcare professionals and patient organizations need to work with schools to support them to maintain the safety of pupils with food allergies.

The food industry is another major component to the safety of patients with food allergies (Chapter 6.1). Food allergen management by the food industry suffers from a lack of knowledge on the level of allergen required to precipitate a significant allergic reaction plus suboptimal analytical systems to detect small amounts of allergenic foods. This has led to the frequent, and probably overuse of precautionary “may contain ….” labels resulting in many patients ignoring such messages. There is an urgent need for evidence-based references doses for all allergenic foods and data about the impact of co-factors on these doses. These data would inform improved allergen management systems. It is then critical that the food industry works with patient groups and regulators to develop labelling that better communicates the risk of individual products, while acknowledging that risk can never be zero. This would allow patients to make better decisions minimizing risk while maximizing their quality of life.

Great discoveries have been made in the last decade resulting in the improved understanding and clinical management of patients with food allergy and at risk of anaphylaxis. These have been documented in the EAACI Food Allergy and Anaphylaxis Guidelines. Many children, adolescents and adults continue to be affected by food allergy and continue to be at risk of anaphylaxis. There is therefore a continued need to focus resources on food allergy and anaphylaxis to better understand these clinical problems and how to better prevent and manage them. Major advances are expected in the next decade. For this purpose these guidelines are planned to be updated by 2017 or even earlier if significant progress will be available beforehand.
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