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Allergen immunotherapy for the prevention of allergy: a systematic review and meta-analysis

1Maria Kristiansen, 2Sangeeta Dhami, 3Gopal Netuveli, 4Susanne Halken, 5Antonella Muraro, 6Graham Roberts, 7Desiree Larenas-Linnemann, 8Moises A Calderón, 8Martin Penagos, 9George Du Toit, 10Ignacio J Ansotegui, 11Jörg Kleine-Tebbe, 12Susanne Lau, 13Paolo Maria Matricardi, 14Giovanni Pajno, 15Nikolaos G Papadopoulos, 16 17Oliver Pfaar, 18Dermot Ryan, 8Alexandra F. Santos, 19Frans Timmermanns, 20Ulrich Wahn, 21A Sheikh.

Corresponding author: Sangeeta Dhami
sangeetadhami@hotmail.com

1Department of Public Health, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark; 2Evidence-Based Health Care Ltd, Edinburgh UK; 3Institute for Health and Human Development, University of East London, UK; 4Hans Christian Andersen Children’s Hospital, Odense University Hospital, Odense, Denmark; 5The Referral Centre for Food Allergy Diagnosis and Treatment Veneto Region. Department of Mother and Child Health – University of Padua. Padua, Italy; 6The David Hide Asthma and Allergy Research Centre, St Mary’s Hospital, Newport Isle of Wight, NIHR Respiratory

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Abstract

Background: There is a need to establish the effectiveness, cost-effectiveness and safety of allergen immunotherapy (AIT) for the prevention of allergic disease.

Methods: Two reviewers independently screened nine international biomedical databases. Studies were quantitatively synthesized using random-effects meta-analyses.

Results: 32 studies satisfied the inclusion criteria. Overall, meta-analysis found no conclusive evidence that AIT reduced the risk of developing a first allergic disease over the short-term (RR=0.30; 95%CI 0.04 to 2.09) and no randomized controlled evidence was found in relation to its longer-term effects for this outcome. There was however a reduction in the short-term risk of those with allergic rhinitis developing...
asthma (RR=0.40; 95%CI 0.29 to 0.54), with this finding being robust to a pre-specified sensitivity analysis. We found inconclusive evidence that this benefit was maintained over the longer-term: RR=0.62; 95%CI 0.31 to 1.23. There was evidence that the risk of new sensitization was reduced over the short-term, but this was not confirmed in the sensitivity analysis: RR=0.72; 95%CI 0.24 to 2.18. There was no clear evidence of any longer-term reduction in the risk of sensitization: RR=0.47; 95%CI 0.08 to 2.77. AIT appeared to have an acceptable side-effect profile.

Conclusions: AIT did not result in a statistically significant reduction in the risk of developing a first allergic disease. There was however evidence of a reduced short-term risk of developing asthma in those with allergic rhinitis, but it is unclear whether this benefit was maintained over the longer-term. We are unable to comment on the cost-effectiveness of AIT.

Keywords: allergen immunotherapy, allergic diseases, allergy, atopy, prevention, sensitization.

BACKGROUND

Over recent decades, allergen immunotherapy (AIT) has been investigated and used for the treatment of allergic rhinitis (AR)/rhinoconjunctivitis, asthma and venom allergy. AR and asthma often co-exist and up to 50% of patients with AR have bronchial hyperreactivity (BHR) (1). Children with AR have over three times greater risk of developing asthma later on in life when compared to those without AR (2), especially those with BHR (3). Studies assessing the long-term effectiveness of AIT–especially in those with AR–suggest that AIT might reduce the risk of developing asthma (4;5). AIT may also result in a reduced risk for development of new allergic sensitization(s) suggesting a possible mechanism through which this protection is conferred (6;7;8). As a consequence, interest has broadened from a sole focus on the therapeutic effects of AIT treatment to one that also includes investigation of the potential preventive effects of AIT.
Several populations might benefit from the preventive effects of AIT. Firstly, in healthy individuals, with or without IgE-sensitization, AIT might prevent the development of allergic diseases. Secondly, in individuals with allergic manifestations at any stage, AIT may prevent the development of other allergic conditions such as the development of asthma in those with AR. Finally, AIT may prevent the development of additional sensitization in patients who are already sensitized, as well as the spreading of allergic sensitization at the molecular level.

The European Academy of Allergy and Clinical Immunology (EAACI) is in the process of developing Guidelines for AIT. This systematic review is one of five inter-linked evidence syntheses conducted in order to provide a state-of-the-art synopsis of the current evidence base in relation to evaluating AIT for the treatment of AR, food allergy, venom allergy, allergic asthma and its role in allergy prevention. The focus of this review is on assessing the preventive capacity of AIT. The information derived from this systematic review will help to inform key clinical recommendations and the identification of future research needs. The potential effect of early introduction of different food allergens into the diet of infants will not be addressed in this review, since it will be covered by the planned update of the prevention part of the EAACI Food Allergy and Anaphylaxis Guidelines.

AIMS

We sought to assess the effectiveness, cost-effectiveness and safety of AIT for the prevention of allergic disease and allergic sensitization.

METHODS

Details of the methodology used for this review, including search terms and filters; databases searched; inclusion and exclusion criteria; data extraction and quality appraisal have been previously reported(9). We therefore confine ourselves here to a synopsis of the methods employed.

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Inclusion criteria

**Patient characteristics**

We were interested in studies on subjects of any age with or without allergic sensitization(s) and subjects with or without allergic disease.

**Interventions and comparators**

We were interested in AIT administered through any route (e.g. subcutaneous (SCIT), sublingual (SLIT)) compared with no intervention, placebo or any active comparator using different allergens (e.g. pollens, house dust mites (HDM)), including modified allergens.

**Outcomes**

Primary outcomes

The primary outcomes of interest were the development of first allergic disease or of a new allergic disease, in those with a previous allergic condition, assessed over the short-term (i.e. <2 years of completion of AIT) and longer-term (i.e. ≥2 years post-completion of AIT) using well defined diagnostic criteria.

Secondary outcomes

Secondary outcomes were: the development of: new allergic sensitization(s) (or allergic immunresponse(s)); spreading of allergic sensitization(s) from one allergen to other non-related allergen(s); spreading of allergic sensitization(s) at molecular level, from one allergenic molecule to other molecules; development of new oral allergy syndrome (OAS); health economic analyses from the
perspective of the health system/payer; and safety as assessed by local and systemic reactions in accordance with the World Allergy Organization’s (WAO) grading system of side-effects(10;11).

**Study design**

We were interested in systematic reviews, randomized controlled trials (RCTs), quasi-experimental studies, health economic analyses, and large case series with a minimum of 300 patients.

**Search strategy**

Our search strategy was conceptualized to incorporate the four elements shown in Figure 1 (Appendix 1). Additional unpublished work and research in progress was identified through discussion with experts in the field (Appendix 2). No language restrictions were employed.

**Quality assessment**

Quality assessment was conducted using established tools as detailed in the protocol(9). Assessments were independently carried out on each study by two reviewers. Any discrepancies were resolved by discussion or, if agreement could not be reached, by arbitration by the third reviewer.

**Data analysis and synthesis**

Data were independently extracted onto a customized data extraction sheet in DistillerSR by two reviewers, and any discrepancies were resolved by discussion or, if agreement could not be reached, by arbitration by a third reviewer.

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A descriptive summary with data tables was produced to summarize the literature. Where possible and appropriate, meta-analysis was undertaken using random-effects meta-analyses using Stata (version 14).

**Sensitivity and subgroup analyses, and assessment for publication bias**

Sensitivity analyses were undertaken by comparing the summary estimates obtained by excluding studies judged to be at high risk of bias with those judged to be at low or moderate risk of bias.

Subgroup analyses were undertaken to compare:

- Children versus adults
- Route of administration
- Allergens used for AIT.

We were unable to assess publication bias through the creation of funnel plots due to the small number of studies, but were able to use Eggar’s test(12).

**Registration and reporting of this systematic review**

This systematic review is registered with PROSPERO with registration number: CRD42016035380 . It is reported in accordance with the PRISMA guidelines (Appendix 3).
RESULTS

Overview of studies

We identified a total of 10,704 potentially eligible studies after removal of duplicates. Of these, 32 studies reported in 34 publications and one entry into an online trial repository fulfilled the inclusion criteria (Figure 2)(3;6-8;13-43).

In terms of study design, 17 RCTs and 15 controlled-before-after (CBA) studies were identified. The key characteristics and main findings of the RCTs can be found in Table 1 and for the CBAs in Table 2. Nineteen studies included children; eight studies enrolled adults only; and five studies included both child and adult subjects. The numbers of subjects included in these studies varied from 28-691 for the majority (N=30) of studies. However, two CBAs reported on substantially larger populations: 8,396 subjects(7), and 118,754 subjects(16), respectively.

The allergens in the AIT studied were HDM, peach, pollen from grass, birch, ragweed, Japanese cedar or Parietaria Judaica, Cladosporium herbarum, Penicillium notatum, Aspergilus fumigatus, Alternaria alternata, Mucor racemosus, Quercus alba, Cynodon dactylon, Ambrosia elatior, Plantago lanceolata, Phileum pratense/Dactylis glomerata/Lolium perenne (PDL) grass mix, Dermatophagoides pteronyssinus and Dermatophagoides farinae, either as single allergens or as multiple allergens. Peach was the only food allergen included in the identified AIT studies. The routes of administration were SCIT, oral and SLIT in the form of tablets and drops.

The overall quality of the identified RCTs varied with five RCTs judged to be at low risk of bias(8;14;19;31;42) six at medium risk(13;18;23;24;35;40) and six at high risk of bias(3;17;22;25;28;37). All CBAs were judged to be at high risk of bias (Tables 3 and 4).

Our main findings are presented according to primary and secondary outcomes of the review.
Primary outcomes: development of new allergic disease

We identified 12 studies reported in a total of 14 publications and an entry into an online trial repository on the effectiveness of AIT for the prevention of development of new allergic disease in previously healthy subjects or in subjects already suffering from one or more allergic disease(3;8;13;15-25). All except the study by Schmitt(16) were RCTs. The Preventive Allergy Treatment (PAT) study reported two updates from the same trial (i.e. three reports in total)(3;20;21).

Three RCTs investigated the preventive effects of AIT in relation to development of the first allergic disease in healthy asymptomatic individuals. They focused on the effect of SLIT on cedar pollinosis(25), eczema, wheeze and food allergy(8), and asthma(13), respectively.

The majority of studies (N=8) focused on the preventive effect of AIT in relation to the development of asthma in patients with established AR(3;14;15;17-24). SCIT was used in four of these RCTs (3;17-21) whilst SLIT through drops or tablets were used in four RCTs(14;15;22-24). In the CBA study using routine healthcare data, patients were stratified according to mode of administration (i.e. SCIT, SLIT drops, SLIT tablets, and combinations of SCIT and SLIT)(16).

Short-term preventive effects of AIT

The short-term preventive effect of AIT was investigated in two RCTs judged to be at low risk of bias(8;19), three RCTs at medium risk of bias(18;23;24), two RCTs at high risk of bias(22;25), and one CBA at high risk of bias(16).
In terms of mode of administration, SCIT was used in two RCTs(18;19), oral (drops or capsules) (8;23) and SLIT (tablets and drops) in the remaining three RCTs(8;23;24). In the CBA, SCIT, SLIT drops and SLIT tablets were administered(16).

RCTs on short-term preventive effects

Prevention of the onset of first allergic disease

The potential effects of oral AIT for the primary prevention of atopic eczema, wheeze, food allergy and sensitizations were investigated in a recent RCT at low risk of bias by Zolkipli.(8) Infants at high risk of atopy based on family history of allergic diseases were randomized to receive either oral HDM AIT (drops) or placebo twice daily for a year. Upon completion of the trial, no significant difference was seen between the active or placebo groups in the risk of developing eczema (P=0.20), wheeze (P=0.40) or food allergy (P=0.26) in these children(8).

A second RCT by Yamanaka, at high risk of bias, looked at primary prevention in asymptomatic adults sensitised to Japanese cedar pollen. They were randomized to SLIT or placebo and in the second year none of the active group had developed pollinosis compared to seven in the placebo group (P=0.0098)(25).

Meta-analysis of data from these two trials showed no overall reduction in the risk of developing a first allergic disease: RR=0.30 (95%CI 0.04 to 2.09) (Figure 3). Sensitivity analysis excluding Yamanaka did not alter this conclusion.
An RCT at low risk of bias by Grembiale, investigating the preventive effects of SCIT administered for a two-year period to subjects with AR, found no significant differences in asthma prevalence at the end of the trial among the AIT group compared to controls (P=0.49)(19).

The RCT at medium risk of bias by Crimi investigated the effect of SCIT for three years on the development of asthma and BHR among 30 non-asthmatic adults with seasonal AR who were mono-sensitized to Parietaria judaica(18). No significant differences in preventive effect were identified across intervention and control group. At the end of the trial, 47% of patients in the placebo group (7/15) had developed asthma compared to 14% (2/14) in the SCIT group (P=0.056)(18).

The RCT by Moller, at medium risk of bias, randomized 30 children with AR to birch pollen to AIT capsules or placebo(23). They found no cases of asthma at the end of the 10-month treatment period in the AIT group and five cases out of 16 in the control group (P-value not given).

The large RCT by Novembre, at medium risk of bias, randomized 113 children, aged 5-14 with hay fever to grass pollen to SLIT drops co-seasonally for three years or conventional pharmacotherapy(24). At the end of the three year trial, the relative risk of developing asthma was 3.8 (95%CI 1.5 to 10.0; P=0.041) in control subjects compared to the SLIT group(24).

In the RCT by Marogna, at high risk of bias, 216 children with AR and intermittent asthma were randomized to SLIT or conventional pharmacotherapy for a period of three years. They found a lower occurrence of asthma in the SLIT group (30/66, 45.4%) compared with the control group (OR=0.04; 95%CI 0.01 to 0.17)(22).
Random effects meta-analysis of these five RCTs plus the short-term effects of the first publication from the PAT trial (20) demonstrated a significant reduction in the risk of developing asthma: RR=0.40 (95%CI 0.29 to 0.54) (Figure 4). There was no evidence of publication bias (P=0.27). This result remained significant after excluding the trial by Marogna and Moller (2002), which were both judged to be at high risk of bias: RR=0.38 (95%CI 0.20 to 0.72). Subgroup analyses showed that AIT was beneficial in those:

- aged <18 (RR=0.40; 95%CI 0.26 to 0.61), but not in those aged ≥18 years (RR=0.28; 95%CI 0.07 to 1.15)
- receiving SLIT (RR=0.33; 95%CI 0.21 to 0.50) and those receiving SCIT (RR=0.49; 95%CI 0.32 to 0.77)
- receiving pollen AIT (RR=0.48; 95%CI 0.33 to 0.71), but not those receiving HDM AIT (RR=0.20; 95%CI 0.01 to 3.94).

CBAs on short-term preventive effects

**Prevention of the onset of first allergic disease**

We found no relevant studies.

**Prevention of onset of asthma in those with established AR**

Only one CBA investigated the preventive effects of AIT(16). The study by Schmitt looked at 118,754 patients with AR, but with no comorbid asthma, between 2007-12. Patients were stratified according to exposure to AIT in 2006 and followed to assess incident asthma. The authors reported a preventive effect of AIT on the progression from AR to asthma in patients exposed to AIT through any mode of administration (RR=0.60; 95%CI 0.42 to 0.84; P=0.003) compared to unexposed patients. When subdivided according to route of administration, there was a significant preventive effect of SCIT (RR=0.57; 95%CI 0.38 to 0.84; P=0.005) whereas effects of SLIT drops and combinations of SCIT and SLIT did not reach statistical significance(16).
Long-term preventive effects of AIT

There were four RCTs, one judged to be at low risk (15), one to be medium risk (13) and two assessed to be of high risk of bias (3, 17) investigating the longer-term preventive effects of AIT.

RCTs on long-term preventive effects

Prevention of onset of first allergic disease

We found no relevant studies.

Prevention of onset of asthma in those with established atopic dermatitis or AR

An RCT at medium risk of bias explored the effect of 12 months of daily SLIT on prevention of asthma and new sensitizations in children with atopic dermatitis and sensitization to one or more food allergens (13). As no differences in antibody levels between the SLIT and the placebo group could be identified six months into the trial, recruitment was terminated and the trial reduced to pilot study status. After 48 months of follow-up, there were no differences in asthma prevalence between the two groups (13).

A large yet unpublished trial at low risk of bias explored the effect of SLIT tablets on the prevention of asthma in 812 children with grass pollen allergic rhinoconjunctivitis. Based on data available in EudraCT, the trial, undertaken in mono-sensitized children carried out over a five year period with three years of treatment and two years of follow-up study, failed to demonstrate the preventive effect of AIT on the development of asthma (OR=0.9; (95%CI 0.57 to 1.43) (14, 15).
A third RCT by Jacobsen, at high risk of bias, explored the preventive effects of SCIT in relation to onset of asthma over a 10-year follow-up period. This trial enrolled 205 children with seasonal AR at baseline who were randomized to a three-year course of SCIT or no intervention. At 10-years follow-up, the adjusted treatment effect showed a significantly higher OR of not having asthma of 4.6 (95% CI 1.5 to 13.7) among subjects treated with SCIT compared to controls.

The RCT by Song, at high risk of bias, looked at patients with AR, allergic to HDM, two years after discontinuation of three years of SCIT compared to standard pharmacotherapy. They found that no (0/51) patients in the SCIT group developed asthma compared to 9/51 in the control group (P-value not given).

Meta-analysis showed no overall evidence of reduction in the long term risk of developing asthma: RR=0.62; (95% CI 0.31 to 1.23) (Figure 5).

Secondary outcomes

We were planning to assess a range of six different secondary outcomes according to the protocol. However, we did not find studies related to spreading of allergic sensitization(s) at the molecular level, nor did we identify studies exploring development of new OAS after the end of the intervention or health economic analyses of AIT used for prevention.

In the sections below, findings related to development of new allergic sensitization(s) and safety will be described.
**Development of new allergic sensitization**

We found 23 studies investigating the effect of AIT on the development of new allergic sensitizations (6-8;17;22;26-43) including one trial reported in two publications(29;30). Nine studies were RCTs (8;17;22;28;31;35;36;40;42) and three of these(8;31;42) were assessed to be at low risk of bias. The remaining studies were all CBAs assessed to be at a high risk of bias. Of these, 12 (six RCTs and six CBAs) provided data on short-term effects and 11 (three RCTs and eight CBAs) provided data on long-term effects.

**Short-term preventive effects**

**RCTs**

There were six RCTs investigating this outcome. Three low risk of bias RCTs investigated the short-term effects of AIT on the risk of developing new sensitizations (8;31;42). The remaining three RCTs were moderate(40) or high risk of bias(22;36).

The Zolkipli HDM oral AIT trial among infants at high risk of developing allergic disease found a significant reduction in sensitization to any common allergen in the active group compared to the placebo group (P=0.03) at the end of the trial, but no difference in HDM sensitization between the AIT (5.7%) and control groups (7.8%): risk difference: 2.2%; 95%CI -7.5 to 11.8; P=0.61(8).

Garcia studied adult patients allergic to peach, and found no relevant new sensitizations in the placebo group (n=17) and three new sensitizations to single allergens among the 37 patients in the SLIT group after six months of treatment; the AIT was therefore judged to be ineffective(31).
The RCT by Szépfalusi looked at the preventive effect of SLIT with grass pollen or HDM extract in mono-sensitized children aged 2-5 years; they found no difference in the rate of new sensitizations to HDM between groups after 12 and 24 months of SLIT(42).

Three additional RCTs investigating the short-term effects of AIT, of medium to high risk of bias, found significantly lower incidence of new sensitizations among children and adults with AR. The first, Marogna, found that in the group treated with SLIT for three years, 4/130 developed new sensitizations compared to the controls in whom 23/66 developed new sensitisations (OR=0.06; 95%CI 0.02 to 0.17). They further concluded that the SLIT group was less likely to be polysensitized compared to the SLIT group at year 3: OR=0.33 (95%CI 0.17 to 0.61)(22). A second RCT conducted by Marogna found a significantly lower incidence of new sensitizations among the SLIT group compared to controls(36). At the end of the three-year treatment period, 16/271 (5.9%) in the SLIT group had developed new sensitizations compared to 64/170 (38%) among controls (P<0.001). The third RCT by Pifferi looked at children with asthma monosensitized to HDM treated with SCIT for three years compared to controls(40). At the end of treatment, they found no new sensitizations in the SCIT group (0/15) compared to 5/14 in the control group (P=0.01).

Meta-analysis showed an overall reduction in the risk of allergic sensitization: RR=0.33 (95%CI 0.12 to 0.93) (Figure 6). The Eggar test showed no evidence of publication bias (P=0.60). Sensitivity analyses excluding the two studies by Marogna, at high risk of bias, however failed to confirm this risk reduction: RR=0.72; 95% CI 0.24 to 2.18.

Subgroup analyses lacked precision, but suggested that AIT was:

- likely to be beneficial in those aged <18 (RR=0.32; 95% CI 0.08 to 1.28), but not in those aged ≥18 years (RR=3.32; 95%CI 0.18 to 60.85)

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- more likely to be beneficial in those receiving ≥3 years therapy (RR=0.13; 95%CI 0.08 to 0.21) than in those receiving <3 years therapy (RR=0.74; 95%CI 0.13 to 4.21)
- more likely to be beneficial in those receiving SCIT (RR=0.09; 95%CI 0.01 to 1.41) than SLIT (RR=0.38; 95%CI 0.13 to 1.13)
- likely to be beneficial in those receiving HDM (RR=0.33; 95%CI 0.09 to 1.20), but not in those receiving peach (RR=3.32; 95%CI 0.18 to 60.85).

CBAs

The inconsistent evidence found in RCTs was also reflected in the included CBAs with four studies finding a lower occurrence of new sensitizations among AIT exposed subjects compared to unexposed subjects(6;34;38;41), one study reporting higher occurrence in the AIT group compared to controls(26), and three studies reporting no differences between groups (Table 2)(33;38;43).

Long term preventive effects of AIT on the development of new allergic sensitization

RCTs

Three RCTs investigated the preventive long term (i.e. post-intervention) effects of AIT on onset of new sensitizations(17;28;35).

The Limb RCT, at medium risk of bias, explored the effect of SCIT for 24 months with a mixture of up to seven aero-allergens among children with moderate-to-severe asthma recruited between 5-12 years of age and followed into adulthood(35). The mean follow-up time of the 82 subjects was 10.8 years. There was a similar development of new sensitivities among both the SCIT and placebo groups (P=0.13), and the types of new sensitivities were also found to be similar across groups(35).
The high risk of bias RCT conducted by Dominicus followed adult patients with allergic rhinoconjunctivitis three years after cessation of SCIT for grass pollen and found that the number of subjects who did not develop new sensitizations were higher in the group exposed to SCIT (20/26; 77%) compared to the placebo group (3/13; 23%; P-value not given) (28).

In an RCT at high risk of bias, Song followed patients with AR two years after cessation of SCIT for HDMs compared to patients receiving pharmacotherapy only(17). In the SCIT group, the occurrence of new sensitizations was 2/43 (4.7%) compared to 17/41 (41.5%) among controls (P<0.01).

Meta-analyses of these studies showed no evidence of a reduction in the long-term risk of allergic sensitization: RR=0.47 (95%CI 0.08 to 2.77) (Figure 7). The Eggar test showed no evidence of publication bias (P=0.23).

**CBAs**

Among the seven CBAs investigating long-term preventive effects of AIT, one SLIT study by Di Rienzo found no significant differences in onset of new sensitizations among intervention and control groups during the 10 years of follow-up(27). Five studies, four SCIT and one SLIT, found reduced onset of new sensitizations among subjects exposed to AIT(7;29;34;37;39).

In contrast to these findings, a SCIT CBA by Gulen found a significantly higher occurrence of new sensitization among children with asthma who were monosensitized to HDM exposed to AIT compared to controls(32).
Cost-effectiveness

We found no studies investigating the cost-effectiveness of AIT for the prevention of allergy.

Safety

We identified a total of seven studies, six SLIT (five of these RCTs and one CBA), and one SCIT RCT, that reported on adverse events.(8;15;22;36;37;40;42).

In the SLIT studies, an RCT at low risk of bias investigating effects of SLIT administered as drops to infants reported no differences in numbers or type of adverse reactions between intervention and control groups (8), and a further RCT with low risk of bias among children between 2-5 years of age also reported no relevant side effects in 21,170 single applications(42). The incidence of generalized itching was reported in three SLIT studies assessed to be at high risk of bias: one RCT finding that 4/271 (1.5%) of the children exposed to SLIT experienced one episode of generalized itching that resolved without therapy(36), another RCT reported one incidence of systemic itching after SLIT among 144 children in the SLIT group(22), and a CBA reported that 5/57 adult patients exposed to SLIT had transient oral itching(37). In an RCT, assessed to be at medium risk of bias, the safety of SCIT was assessed among children aged 6-14 years(40). It reported no major local or systemic effects of AIT during three years of treatment among the 15 patients randomized to SCIT(40).

DISCUSSION

Statement of principal findings

We found no consistent evidence from the limited body of RCT evidence that AIT can prevent the first onset of allergic disease over the short-term and no RCTs investigating the long-term preventive effects of AIT. We did however find clear evidence of a substantial reduced risk of developing asthma in those...
with pre-existing AR over the short-term, although it is unclear if this benefit was maintained over the longer-term. There was some evidence to indicate that the risk of allergic sensitization can be reduced over the short-term, but this was not confirmed in the pre-specified sensitivity analysis. There was no evidence of a long-term reduction in the risk of allergic sensitization. These risks were however in many cases imprecisely estimated and so need to be interpreted with caution. Overall, the safety profile of AIT appeared acceptable, but we found no data on cost-effectiveness considerations and so are unable to comment on this outcome.

Strengths and limitations

The strengths of this study include the comprehensive literature search that was undertaken and adherence to a pre-published protocol with clearly defined objectives and a detailed pre-specified analysis plan. The main limitations relate to the possibility of not uncovering the total body of evidence on this subject and the challenges of interpreting a heterogeneous body of relatively small-scale trial evidence.

Implications for policy, practice and research

This review has highlighted the inconsistent evidence-base and the lack of robust evidence, in particular for long-term preventive effects of AIT and in terms of detailed subgroup analysis, which impedes our ability to tease out clear implications for healthcare policy and clinical practice. In terms of research, there is a need for high quality well powered RCTs with long-term follow-up and well defined diagnostic criteria to answer the above research questions. Furthermore, there is a need for studies with more robust assessment of adherence to AIT to ascertain the dose received and take into consideration the effect of non-adherence to treatment on preventive effectiveness. Future studies should also include possible effect modification caused by measures taken to alter behaviours and/or environmental triggers of allergy (e.g. exposure to passive smoking in childhood, presence of pets) as this may modify the effect of AIT on onset of allergy.
Conclusions

This systematic review found only limited evidence to support the use of AIT in a preventive capacity. Based on the current evidence, we are unable to conclude that AIT prevents the development of first allergic disease. There appears to be short-term benefit in preventing asthma in those with AR, particularly if AIT is started in childhood with this benefit being seen for SCIT and SLIT. It is however unclear if this benefit is maintained over several years post-discontinuation of AIT or indeed whether AIT is a cost-effective intervention.

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Conflicts of interest: M Kristiansen: support to undertake the systematic review, S Dhami: support to co-ordinate the undertaking of the systematic review; S Halken: in the Grazax Asthma prevention study steering committee (ALK-Abello); M A Calderon: lectures honorarium (ALK, Stallergens, Merck and Allergopharma), consultancy honorarium (ALK, Stallergenes and Hal); M Penagos: payment for presentations and travel support from Stallergenes and ALK-Abello; A Muraro: Acting in consulting capacity for ALK, Meda Pharma, Nestle, Nutricia, Novartis. Grants from: Nestlé: Co-investigator for research protocol, Nutricia: Co-investigator for research protocols; G Du Toit: Equity in the FoodMaestro Application. Grants supporting the LEAP Study paid to Kings College, London. Author of the 2015 NEJM LEAP Study manuscripts that do not primarily deal with immunotherapy; Ignacio J Ansotegui: none; J Kleine Tebbe: Consulting fees from various companies (ALK-Abelló, Allergy Therapeutics, Circassia, LETI, Merck USA); lecture fees (ALK-Abelló, Allergopharma, Bencard, Circassia, HAL, LETI, Lovafarma, Novartis, Stallergenes). Fees for participation in review activities from Biotech Tools, LETI, Lofarma, Merck USA. Financial interest in ALK-Abello; D Larenas-Linnemann: none; S Lau:
Research grants by Allergopharma and Symbiopharm, drug monitoring committee Merck. Honorarium Symbiopharm; P Matricardi: Honoraria as speaker and consultant: Anallergo; G Pajno: research grant (Stallergens); N G Papadopoulos: Grant from GSK, NESTLE, MERCK. Consulting fee from GSK, ABBVIE, Novartis, Menarini, Meda, ALK-ABELLO, Allergopharma, Uriach, Stallergenes. Payment for development of educational presentations for Abbvie, Sanofi, Menarini & Meda; G Roberts: Materials for research programme (ALK-Abello), research grant (ALK-Abello), advisory board (ALK-Abello), speaker (Allergy Therapeutics, ALK-Abelo); O. Pfaar: in the past three years received research grants for his institution and/or personal fees for lecturing and/or educational material and/or consultancy and/or coordinating investigator services and/or travelling from ALK-Abelló, Allergopharma, Allergy Therapeutics, Anergis, Bencard, Biomay, Biotech Tools s.a., Circassia, HAL Allergy, LETI, Lofarma, MEDA, Mobile Chamber Experts (a GA2LEN Partner), Novartis, Nuvo, Pohl-Boskamp, Sanofi and Stallergenes. Pfaar is the current chairman of the Immunotherapy Interest Group (IT IG) of the European Academy of Allergy and Clinical Immunology (EAACI) and the secretary of the ENT section of the German Society for Allergology and Clinical Immunology (DGAKI) and chairman or member of different guideline-/task force initiatives of EAACI and DGAKI; D Ryan: Consulting fees from Stallergenes. Payment for presentations: MEDA, Thermo-Fisher; A F. Santos: grants from Medical Research Council (UK), NIAID/Immune Tolerance Network (USA) and support from Department of Health via the National Institute for Health Research (NIHR); F Timmermanns: Funding for Netherlands Anaphylaxis Network (ALK-Abello, MEDA); U Wahn: Speaker’s honoraria: Novartis, ALK, Allergopharma, Stallergenes, Allergy Therapeutics, Nestle, MEDA-pharma,Consultancy: Novartis, ALK, Allergopharma, Stallergenes, Danone, Hipp, MEDA pharma, Biomay; A Sheikh: Support to coordinate the undertaking of the systematic reviews and development of the guidelines.

Supporting information

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Figure 3: Random-effects meta-analysis of effectiveness of AIT in preventing short-term risk of developing first new allergic disease

Figure 4: Random-effects meta-analysis of effectiveness of AIT in short-term prevention of asthma in those with allergic rhinitis

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Figure 5: Random-effects meta-analysis of effectiveness of AIT in long-term prevention of asthma in those with allergic rhinitis

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Table 1: Characteristics and main findings from RCTs

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Table 4: Quality assessment of CBAs

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Figure 1: Conceptualization of systematic review of allergen immunotherapy for the prevention of allergic disease

<table>
<thead>
<tr>
<th>Condition</th>
<th>Interventions</th>
<th>Outcomes</th>
<th>Study designs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Prevention of development of sensitization and/or allergic disease in healthy persons with or without allergic sensitization • Prevention of development of new allergic manifestations in patients with already developed allergic diseases at different stages. • Prevention of spreading of sensitization from one or more allergen(s) to other non-related allergens or from one or more allergenic molecule(s) to other molecules.</td>
<td>• AIT administered through any route i.e. subcutaneous (SCIT), sublingual (SLIT), oral, intranasal, epicutaneous, intra-dermal or intra-lymphatic • AIT for different allergens (e.g. pollens, mites, animal dander, cockroach and moulds) including modified allergens</td>
<td>• Effectiveness • Cost-effectiveness • Safety</td>
<td>• Systematic review +/- meta-analysis &amp; randomized controlled trial (RCT) to assess effectiveness • Quasi-RCTs, non-randomized controlled clinical trials (CCT), controlled before-after (CBA) and interrupted time series (ITS) studies to highlight areas needing further evaluation by RCTs • Cost-effectiveness or cost-utility analysis to assess health economics • Case series (&gt;300 patients) to assess safety</td>
</tr>
</tbody>
</table>
Figure 2: PRISMA flow diagram

- Records identified through database searching: N = 11841
- Additional records identified through other sources: N = 11

Records after duplicates removed: N = 10706

Records screened: N = 10706

Records excluded: N = 10634

Full-text articles assessed for eligibility: N = 72

Full-text articles excluded, with reasons: N = 40
- Incorrect study design = 17
- Incorrect outcome = 14
- Incorrect intervention = 5
- Other = 4

Studies included in qualitative synthesis: N = 32

Studies included in quantitative synthesis (meta-analyses): N = 17
Figure 3: Random-effects meta-analysis of effectiveness of AIT in preventing short-term risk of developing first new allergic disease

Nc=number in control group; Ni=number in intervention group; mode=route of administration of AIT
Figure 4: Random-effects meta-analysis of effectiveness of AIT in short-term prevention of asthma in those with allergic rhinitis

Ne=number in control group; Ni=number in intervention group; mode=route of administration of AIT

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Figure 5: Random-effects meta-analysis of effectiveness of AIT in long-term prevention of asthma in those with allergic rhinitis

Nc=number in control group; Ni=number in intervention group; mode=route of administration of AIT

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Figure 6: Random-effects meta-analysis of effectiveness of AIT in short-term prevention of allergic sensitization

Nc=number in control group; Ni=number in intervention group; mode=route of administration of AIT
Figure 7: Random-effects meta-analysis of effectiveness of AIT in long-term prevention of allergic sensitization

Ne=number in control group; Ni=number in intervention group; mode=route of administration of AIT

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**Table 1: Characteristics and main findings from RCTs**

<table>
<thead>
<tr>
<th>Author/year/country</th>
<th>Number of studies(N)/subjects included(n)/age</th>
<th>Participants: Disease status</th>
<th>Specified primary outcome, and secondary outcomes of interest</th>
<th>Comparators (intervention/controls)/route of administration</th>
<th>Type of allergy and allergens used for AIT</th>
<th>Quality</th>
<th>Main outcome/key findings</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimi, 2004, Italy</td>
<td>n=30</td>
<td>Non-asthmatic subjects with seasonal rhinitis and monosensitized to Parietaria judaica.</td>
<td>Effect on development of asthma and bronchial hyperresponsiveness.</td>
<td>SCIT vs. placebo</td>
<td>Allergic rhinitis.</td>
<td>Medium</td>
<td>A total of 9/29 patients developed asthma symptoms at the end of the study: of these 7 (47%) were in the placebo group, 2 (14%) in the SCIT group (P=0.056).</td>
<td>Authors conclude that Parietaria SCIT appears to prevent natural progression of allergic rhinitis to asthma suggesting that SCIT should be considered earlier in the management of AR, however the results were</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Population</td>
<td>Intervention</td>
<td>Outcome Measures</td>
<td>Results</td>
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<tr>
<td>Grembiale, 2000, Italy</td>
<td>n=44</td>
<td>Subjects with a documented history of atopic rhinitis, no reported symptoms compatible with asthma. Age range: 10-38 yrs.</td>
<td>SCIT vs. placebo</td>
<td>Increasing doses of allergen extract followed by monthly maintenance treatment.</td>
<td>No of the SCIT group developed asthma at the end of the 2-yr treatment period compared to 9% in the placebo group (p=0.49). At end of study, methacholine PD_{20}FEV_{1} was within normal range of 50% of treated subjects (p&lt;0.0001) and it was significantly higher in intervention group compared to placebo group (p&lt;0.0001). No changes in methacholine PD_{20}FEV_{1} in...</td>
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</table>

All subjects had normal lung function test at inclusion and were well matched on methacholine responsiveness at the beginning of the study. All subjects underwent Methacholine challenge after 1 yr and 2 yrs of treatment.
<p>| Holt, 2013, USA and Australia | n=50 | 25 randomized to receive mixture of soluble allergens given daily for 12 months, 25 randomized to placebo. | Children with positive atopic family history; a personal history of atopic dermatitis, and sensitization to one or more food | Effect on development of asthma and sensitizations, safety. | SLIT (drops) vs. placebo. 12 months course of SLIT. Outcome assessment at 48 months. | Atopic dermatitis. House dust mite, cat, timothy grass. | Medium | No difference in asthma prevalence between the two groups (4/25 in SLIT group; 4/25 in placebo group) at 48 months. No difference in antibody titers between active placebo group throughout the study. | Positive correlation between methacholine PD20FEV1 before SCIT and magnitude of improvement in bronchial reactivity suggest that early intervention is likely to be of greater benefit. |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Follow-Up</th>
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</thead>
<tbody>
<tr>
<td>Jacobsen, 2007, multi-sited study (Europe)</td>
<td>n=205 at baseline, 103 randomized to 3 yrs of subcutaneous SIT, 102 served as open control group. Age range at baseline: 6-14 yrs. Total follow up at 10 yrs: n=147 (79 from intervention group, 68 controls). Follow-up at 5 years (2 years after end of treatment): 183. Follow-up at 3 years (end of treatment): 191.</td>
<td>Children with history of birch and/or grass pollen induced seasonal AR.</td>
<td>Effect on development of asthma and bronchial hyperresponsiveness. SCIT vs. no intervention</td>
<td>Longitudinal treatment effect shows OR for non-asthma 4.6 (95% CI: 1.5-13.7) in favour of SCIT group after 10 years. At 5 yrs. follow-up, SCIT-group had significantly less asthma compared to controls (OR 2.68, 95% CI: 1.3-</td>
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<tr>
<td>Niggemann, 2006</td>
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<td>and placebo group at the 6-month sampling point, recruitment was terminated and the study status changed to pilot study.</td>
</tr>
</tbody>
</table>
Result after 3 years i.e. at end of treatment show significantly fewer asthma symptoms among actively treated children compared to controls (OR 2.52, P<0.05).

No significant differences between SCIT and control group in bronchial responsiveness to methacholine in change from baseline of PC20 after 10 years.

Authors conclude that findings from the 10 yrs. follow up demonstrated the long-lasting benefit of SCIT in relation to prevention of asthma.

Marogna, 2008, Italy

n=216
144 randomized to SLIT, 72 received drugs only.
Age range: 5-17 yrs.

Children with allergic rhinitis with/without intermittent asthma.

Effect on development of asthma, new sensitizations and bronchial hyperreactivity.

SLIT vs. pharmacotherapy.
Build-up phase for approx.. 50 days followed by SLIT 3 times a week in the maintenance phase.
SLIT administered as AR, asthma.
Mite, grass, birch, Parietaria.

Low

Higher occurrence of intermittent and persistent asthma in control group (30/66, 45.4%) compared to the SLIT group (17/130, 13.1%).

Patients were followed up for 3 yrs.
Adherence to SLIT was 80% or higher in 73.8% of patients. No
Children with rhinoconjunctivitis.

Effect on development of asthma and safety (part of aim of studying immune responses during OIT).

Oral (capsules) vs. placebo.

Treatment with capsules continued for 10 months.

Birch.

Möller, 1986, Sweden

n=30
14 randomized to active capsules (birch pollen preparation), 16 to placebo.
Age range: 8-16 yrs.

No development of asthma in oral IT arm compared with 5 patients in the placebo arm.

Similiar side effects noted (nausea, abdominal colic, diarrhea) in both groups.

Medium

Similar side effects noted (nausea, abdominal colic, diarrhea) in both groups.

One patient reported systemic itching

Reduced onset of new sensitizations and intermittent or mild persistent asthma, and decreased bronchial hyperreactivity in children 3 years after treatment.

Increased rate of polysensitizations in control group compared to SLIT group (OR SLIT vs. control at yr. 3: 0.33; 95% CI, 0.17-0.61).

Lower occurrence of new sensitizations in SLIT group (4/130) than among controls (23/66) (OR 0.06; 95% CI, 0.02-0.17).

Difference in dropout frequency between groups.

Reduced occurrence of new sensitizations in mites, 41 for grasses, 4 for birch, and 1 for Parietaria

98 for mites, 41 for grasses, 4 for birch, and 1 for Parietaria

Safety.

Includes:

- Children with rhinoconjunctivitis.
- Effect on development of asthma and safety (part of aim of studying immune responses during OIT).
- Oral (capsules) vs. placebo.
- Treatment with capsules continued for 10 months.
- Birch.

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Reduced onset of new sensitizations and intermittent or mild persistent asthma, and decreased bronchial hyperreactivity in children 3 years after treatment.

Increased rate of polysensitizations in control group compared to SLIT group (OR SLIT vs. control at yr. 3: 0.33; 95% CI, 0.17-0.61).

Lower occurrence of new sensitizations in SLIT group (4/130) than among controls (23/66) (OR 0.06; 95% CI, 0.02-0.17).

Difference in dropout frequency between groups.

Reduced occurrence of new sensitizations in mites, 41 for grasses, 4 for birch, and 1 for Parietaria

98 for mites, 41 for grasses, 4 for birch, and 1 for Parietaria

Safety.
| Novembre, 2004, Italy | n=113  
54 randomized to SLIT group,  
59 randomized to standard  
symptomatic therapy.  
Age range: 5-14 yrs. | Children with hay fever limited to grass pollen. | Effect on development of asthma.  
SLIT (drops) vs. pharmacotherapy.  
A 3-year coseasonal protocol was used  
consisting of build-up and maintenance phases  
with an extract of mixed grass pollens. SLIT was administered for 4  
months a year. | Hay fever due to grass pollen.  
Mixed grass pollens. | Medium | At entry into the study, no subject  
reported seasonal asthma with more than 3  
episodes per season.  
Relative risk of development of asthma after 3  
years was 3.8 (95 CI; 1.5-10.0) in control group  
compared to intervention group.  
After first year of treatment, 6 of the SLIT patients  
had asthma compared to 6 in the control group. After the  
second year, 7 SLIT patients and 16 controls  
had asthma (p=.058). After the third year, 8  
SLIT patients and 18 controls had asthma  
(P=.0412).  
No systemic reactions seen. |
<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Sample Size</th>
<th>Participants</th>
<th>Intervention</th>
<th>Comparator</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Song, 2014, China</td>
<td>n=102</td>
<td>Patients with AR allergic to house dust mites</td>
<td>Effect on onset of asthma and development of new sensitizations</td>
<td>SCIT vs. pharmacotherapy</td>
<td>SCIT for 3 yrs. with initial updosing followed by maintenance once every 6 weeks for 3 yrs.</td>
<td>In the SCIT group no patients developed asthma and few new sensitizations occurred (2/43, [4.7%]). In the control group, 9/41 (22%) developed asthma and 17/41 (41.5%) new sensitizations. Differences were statistically significant (p&lt;0.01). Authors conclude that early application of SCIT can prevent the development of asthma.</td>
</tr>
<tr>
<td>Valovirta, multinational (11 European countries)</td>
<td>n=812 after seven months of screening</td>
<td>Patients with grass pollen-induced AR, without asthma, and no overlapping symptomatic allergies</td>
<td>Time to onset of asthma</td>
<td>SLIT vs. placebo once daily for 3 years, followed by a blinded observational period of 2 years.</td>
<td>In SLIT group of 398 patients 34 developed asthma and in the control group of 414, 39 developed asthma defined by strict diagnostic criteria including beta-2- Not yet published but data available at EudraCT</td>
<td></td>
</tr>
<tr>
<td>Yamanaka, 2015, Japan</td>
<td>( n = 29 ) (27 due to withdrawal during the course of the study). 13 were randomized to SLIT group, 14 to placebo group. Age range: 18-52 yrs.</td>
<td>Asymptomatic subjects sensitized to Japanese cedar pollen.</td>
<td>Effect on development of cedar pollinosis. SLIT vs. placebo. SLIT group received graded extracts of standardized Japanese cedar pollen followed by maintenance therapy.</td>
<td>Sensitized to pollen. Japanese cedar pollen. Low</td>
<td>No significant difference in development of symptoms of pollinosis between groups after first year of treatment (4 in SLIT/1 in placebo group). In the second year, 7 of the placebo group and none of the SLIT group developed</td>
<td>Significant increase in IL-10 producing T cells and B cells in SLIT group, Significant decrease in IL-10 producing</td>
</tr>
</tbody>
</table>
Ratio of development of pollinosis in the SLIT group was significantly lower than in the placebo group in the second year of the trial \( (p=0.0098, \text{ Fisher's exact test}) \).

| Zolkpili, 2015, United Kingdom | n=111 | 57 assigned to house dust mite oral IT, 54 assigned to placebo. | Infants at high risk of atopy (2 or more first-degree family members with allergic diseases (asthma, AR, eczema, or food allergy) but negative skin prick test responses to common allergens at randomization. | Effect on development of eczema, wheeze, and food allergy; development of sensitizations and, and adverse events/safety. | Oral AIT (drops) vs. placebo. | High risk. | High | No effect on house dust mite sensitization, eczema, wheeze, and food allergy. Significant reduction \( (P=0.03) \) in sensitization to any common allergen \( (16\% \pm 95\% CI 1.7\%-30.4\%) \) in the active group \( (5\%[9.4\%]) \) compared to the placebo group \( (13\%[25.5\%]) \) after 12 months of treatment. | Children were assessed every 3 months. Differences in morbidity and pet ownership across groups did not influence direction or size. |

Children were assessed every 3 months.
Dominicus, 2012, Germany

n=154

77 patients were randomized to receive SCIT with grass pollen, 77 were assigned to placebo group.

Follow-up included 26 patients from ex-SCIT group and 13 control patients.

Age range: 18-60 years.

<table>
<thead>
<tr>
<th>Adult patients allergic to grass pollen with rhinoconjunctivitis with or without asthma.</th>
<th>Effect on development of new sensitizations.</th>
<th>SCIT vs. placebo.</th>
<th>Grass pollen allergy.</th>
<th>Low</th>
<th>Number of patients who did not develop new sensitizations during the 3 year’s follow-up after cessation of SCIT was higher in Ex-SCIT group (20 patients, 77%) compared to control group (3 patients, 23%).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients received weekly pre-seasonal subcutaneous immunotherapy with either grass pollen extract or placebo for 2 yrs. Both groups received active treatment in the third treatment yr.</td>
<td>Grass pollen.</td>
<td></td>
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<td></td>
<td>This prospective follow-up study ended 3 yrs after cessation of SCIT. Authors conclude that SCIT has long-term effects in reducing onset of new sensitizations.</td>
</tr>
</tbody>
</table>

Secondary outcome: Development of new allergic sensitization(s) (or allergic immunresponse(s)) after end of intervention.

Treatment was well tolerated with no differences in numbers or nature of adverse events between groups. Of estimated differences in outcomes.
<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Age Range</th>
<th>Study Design</th>
<th>Intervention</th>
<th>Duration of Treatment</th>
<th>Outcome</th>
<th>Sensitization Details</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>García, 2010, Spain</td>
<td>56</td>
<td>18-65 yrs.</td>
<td>37 patients were randomized to the SLIT group, 17 were in the placebo group.</td>
<td>SLIT vs. placebo. Treatment with standardized peach extract or placebo continued for 6 months.</td>
<td>High</td>
<td>New sensitizations.</td>
<td>New sensitization were to single allergens and rated as of scarce magnitude and no clinical relevance.</td>
<td></td>
</tr>
<tr>
<td>Limb, 2006, USA</td>
<td>82</td>
<td>5-12 yrs.</td>
<td>41 were randomized to immunotherapy, 41 to placebo.</td>
<td>SCIT vs. placebo. SCIT was given with a mixture of up to seven aeroallergen extracts and maintenance injections continued every 2 weeks for 24 months, and every 3 weeks until debriefing.</td>
<td>Medium</td>
<td>Similar acquisition of new skin test sensitivities from time of randomization into original childhood trial to debriefing (15 vs. 20%; p=0.28) and to adult follow-up (30 vs. 31%; p=0.75) among both SCIT and placebo group.</td>
<td>The 82 evaluated patients did not differ from the remaining 39 patients from the original trial with regard to age, ethnicity, gender, number of positive sensitizations.</td>
<td></td>
</tr>
<tr>
<td>in the placebo group acquired one or more new sensitivity between randomization and debriefing (p=0.19).</td>
<td>skin tests or treatment-designated allergens at randomization, or total serum IgE (all p-values &gt;0.1).</td>
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<tr>
<td>From debriefing to adult follow-up, 38/40 (95%) in the SCIT group vs. 33/39 (85%) in the placebo group acquired at least one more new sensitivity.</td>
<td>Long-term evaluation of broad-spectrum IT (mean follow-up 10.8 yrs).</td>
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<tr>
<td>Types of new sensitivities</td>
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</tbody>
</table>
Marogna, 2004, Italy

<table>
<thead>
<tr>
<th>n=511</th>
<th>Patients with allergic rhinitis with/without intermittent asthma.</th>
<th>Effect on development of new sensitizations, safety/adverse events.</th>
<th>SLIT vs. pharmacotherapy.</th>
<th>AR, asthma.</th>
<th>Low</th>
<th>Significantly lower incidence of new sensitizations in SLIT group (16/271 [5.9%]) compared to pharmacotherapy group (64/170 [38%]) at the end of the 3-ys. treatment period (p &lt; 0.0001).</th>
</tr>
</thead>
<tbody>
<tr>
<td>319 patients were randomized to SLIT, 192 patients to control group.</td>
<td>Patients were evaluated in an observation period of 1 yr, followed by SLIT prescribed for relevant allergens in a build-up and maintenance phase for approximately 3 yrs.</td>
<td></td>
<td></td>
<td>Mites, grass, birch, parietaria, mugworth.</td>
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<tr>
<td>Mean age SLIT group = 22.8 yrs</td>
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<tr>
<td>Mean age control group = 21.5 yrs.</td>
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<tr>
<td>Study</td>
<td>Participants</td>
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<td>Comparison</td>
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<tr>
<td>Pifferi, 2002, Italy&lt;br&gt;n=29&lt;br&gt;15 patients were randomized to SCIT group, 14 to control group. Age range: 6-14 yrs.</td>
<td>Children with asthma and monosensitized to house dust mite.</td>
<td>SCIT vs. Pharmacotherapy (?)&lt;br&gt;SCIT continued for 3 yrs.&lt;br&gt;Effect on development of new sensitizations, bronchial hyperreactivity and safety.</td>
<td>Asthma, AR. House dust mite.</td>
<td>SCIT group showed significant decrease in non-specific bronchial hyperreactivity. The ratio of incidence of “non-improvement” in bronchial reactivity in the SCIT group compared to controls was 0.3; 95%CI 0.11-0.87). No new sensitivity occurred in SCIT group whilst medium. Four dropouts in control group. Treatment and control groups were matched for age, asthma severity, respiratory function and bronchial symptoms.</td>
<td>No significant overall difference between the two groups. Five dropouts in SLIT group due to adverse events (oral itching, asthma, abdominal pain). All SCIT patients reached the suggested dose for maintenance phase.</td>
<td></td>
</tr>
</tbody>
</table>
| Study | n=31  
Austria | 15 randomized to SLIT group with either grass pollen or house dust mite extract according to the individual sensitization profile), 16 randomized to placebo group. Age range: 2-5 yrs. | Healthy persons with allergic sensitizations but no clinical disease. Safety. | Effect on development of new sensitizations.  
SLIT vs. placebo. After dose-up phase, therapy continued for 2 yrs. | Sensitization to pollen and/or mites.  
House dust mite, grass. | High | Preventive application of SLIT in young children was safe (no relevant side effects in 21,170 single applications). No difference in rate of new sensitizations in SLIT group compared to placebo group after 12 and 24 months of treatment. Verum-treated patients had a significant up-regulation of hyperreactivity.  
Children were mono/oligoclonally sensitized, clinically asymptomatic. Rate of new sensitizations increased significantly over time in both |
allergen-specific IgG (p<0.05) and IL10-dependent inhibition was observed in vitro in treatment group but not in placebo group.
Table 2: Characteristics and main findings from CBAs

<table>
<thead>
<tr>
<th>Author/year/country</th>
<th>Number of studies(N)/subjects included(n)/age</th>
<th>Participants: Disease status</th>
<th>Specified primary outcome, and secondary outcomes of interest</th>
<th>Comparators (intervention/controls) / route of administration</th>
<th>Type of allergy and allergens used for AIT</th>
<th>Quality</th>
<th>Main outcome/key findings</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schmitt, 2015, Germany</td>
<td>n=118,754 stratified into one group exposed to AIT in 2006 (n=2,431) or an unexposed group (n=116,323)</td>
<td>Patients with AR but without comorbid asthma. AR at least two ICD-10 codes for AR.</td>
<td>Effect on onset of asthma. AIT stratified as SCIT, SLIT drops, SLIT tablets, and combinations.</td>
<td>Asthma. All types of allergens used for AIT included.</td>
<td>Low</td>
<td>Risk of incident asthma was significantly lower in patients exposed to AIT (RR, 0.60; 95% CI, 0.42-0.84) compared to patients not exposed to AIT in 2006. Sensitivity analyses found significant preventive effects of SCIT (RR, 0.57; 95% CI, 0.38-0.84) and AIT including native allergens (RR, 0.22; 95% CI, 0.02-0.68) but no statistical significance.</td>
<td>Consecutive cohort of patients based on routine health care data from German National Health Insurance beneficiaries. Exposed and unexposed groups were observed for incident asthma.</td>
<td></td>
</tr>
</tbody>
</table>
Asero, 2004, Italy  
284 patients received SCIT as part of routine outpatient care, 407 not undertaking SCIT served as controls.  
Age range: >12 years  

<table>
<thead>
<tr>
<th>Patients</th>
<th>Effect on development of new sensitizations</th>
<th>SCIT/pharmacotherapy.</th>
<th>Sensitization to pollen.</th>
<th>Low</th>
<th>Significantly higher prevalence of new sensitizations to ragweed and/or birch pollen in subjects receiving SCIT (132/284; 46%) than among controls (95/407; 23%) (p&lt;0.001).</th>
<th>No preventive effect against denovo sensitizations to birch and ragweed pollen</th>
</tr>
</thead>
<tbody>
<tr>
<td>monosensitized to airborne allergens (grass, pellitory, ragweed, birch or house dust mite) first seen between Jan 1st 1989-Dec 31st 1998 and reevaluated no less than 2 years after the first visit</td>
<td>SCIT was administered following a perennial schedule. Patients enrolled in SCIT treatment according to own choice.</td>
<td>Grass, pellitory, birch, ragweed, house dust mite.</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Secondary outcome: Development of new allergic sensitization(s) (or allergic immunresponse(s)) after end of intervention

Authors conclude that AIT effectively prevents asthma in patients with AR in a real-world setting.
the end of SCIT.

Weekly doses given during build-up phase followed by maintenance doses.

Denovo sensitizations to other airborne allergens (besides ragweed and birch pollen) were rare and did not show any difference between SCIT and control groups.

| Des Roches, 1997, France | n=44 | 22 patients received SCIT, 22 age-matched patients served as controls. | Age range: 2-6 yrs. | Children with asthma and monosensitized to house dust mite. | Effect on development of new sensitizations | SCIT vs. pharmacotherapy. | Asthmatic children sensitized to house dust mites. | Low | Ten of 22 children in SCIT group (45%) did not develop new sensitizations compared to none of the 22 children in the control group. Occurrence of new sensitizations was thus significantly less in SCIT group compared to controls (p<0.001). | The findings suggest that SCIT in asthmatic children monosensitized to house dust mites alters the natural course by preventing the development of new sensitizations. |

Follow-up on an annual basis for 3 yrs.

Dermatophagoides pteronyssinus extract.

Denovo sensitizations to other airborne allergens (besides ragweed and birch pollen) were rare and did not show any difference between SCIT and control groups.

The findings suggest that SCIT in asthmatic children monosensitized to house dust mites alters the natural course by preventing the development of new sensitizations.
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Interventions</th>
<th>Outcomes</th>
<th>Sensitization Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Di Rienzo, 2003, Italy</td>
<td>n=60</td>
<td>Children with AR and/or mild to moderate asthma due to house dust mites.</td>
<td>Effect on development of new sensitizations.</td>
<td>SLIT vs. pharmacotherapy. SLIT was administered continuously for 4-5 yrs. according to guidelines. House dust mite.</td>
</tr>
<tr>
<td></td>
<td>35 accepted treatment with SLIT, 25 received only medication.</td>
<td></td>
<td></td>
<td>AR with/without asthma. 28 children were monosensitized to mites alone, the remaining patients had concomitant sensitizations.</td>
</tr>
<tr>
<td></td>
<td>Age range: 3-17, mean age 8.5 yrs.</td>
<td></td>
<td></td>
<td>No significant difference in onset of new sensitizations in the two groups. Only 3/35 patients in SLIT group and 2/25 patients in control group developed new sensitizations during the 10 yrs. period.</td>
</tr>
<tr>
<td>Eng, 2006, Switzerland</td>
<td>n=28 included in the original study and self-assigned to receive either SCIT (n=14) or standardized pharmacotherapy (n=14) for 3 yrs.</td>
<td>Children with a history of severe grass pollen AR for at least 2 yrs. with/without asthma but with immunoglobulin (IgE)-mediated sensitivity to seasonal allergens only (grass pollen with/without tree)</td>
<td>Effect on development of new sensitizations.</td>
<td>SCIT vs. pharmacotherapy. Grass pollen SCIT was administered pre-seasonally for 3 years. Grass.</td>
</tr>
<tr>
<td></td>
<td>At 6 yrs. follow-up after</td>
<td></td>
<td></td>
<td>AR, asthma. Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Six yrs. after discontinuation of SCIT, a significantly lower number of SCIT patients had developed new sensitizations (8/13) compared to controls (10/10) (p&lt;0.02). The two study groups were matched for gender, age, prevalence of seasonal asthma, and development new sensitizations.</td>
</tr>
</tbody>
</table>
At 12 yrs. of follow-up, 12 SCIT patients and 10 controls were included.

Age range at inclusion: 5-16 yrs.

There was a significantly lower occurrence of new sensitizations in SCIT group compared to controls at 12-yrs follow-up (58% vs. 100%; p<0.05).

This prospective follow-up study finds a reduction in onset of new sensitizations yrs after discontinuation of SCIT. The reduction is sustained at 12 yrs. of follow-up.
<p>| Harmanci, 2010, Turkey | n=122 patients. 62 patients accepted SCIT, remaining 60 patients were treated with medication only. Age range: 8-18 yrs. | Children with intermittent asthma with/without AR, monosensitized to house dust mite. | Effect on development of new sensitizations. SCIT vs. pharmacotherapy. SCIT was administered for four yrs. | Asthma with/without AR. House dust mite. Low | Sensitizations. Significantly higher prevalence of new sensitizations in SCIT group (31/68; 45.5%) compared to controls (10/55; 18.1%) (OR 3.77, 95% CI, 1.52-9.5, p=0.001). | History of atopy and development of new allergic sensitizations. Authors conclude that SCIT may not prevent onset of new sensitizations after the 4-yrs. study period. A total of 36/53 (67.9%) patients in SCIT group had no new sensitizations compared to 38/52 (73.0%) in control group (P=0.141). |</p>
<table>
<thead>
<tr>
<th><strong>Inal, 2007, Turkey</strong></th>
<th>n=147</th>
<th><strong>Children with rhinitis and/or asthma monosensitized to house dust mite.</strong></th>
<th><strong>Effect on development of new sensitizations.</strong></th>
<th><strong>SCIT vs. pharmacotherapy.</strong></th>
<th><strong>AR/asthma.</strong></th>
<th><strong>Low</strong></th>
<th><strong>At 5 year follow-up, a total of 64/85 (75.3%) in the SCIT group showed no new sensitizations compared to 29/62 children (46.7%) in the control group (P=.002).</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>45 patients underwent SCIT with absorbed extracts, 40 patients underwent SCIT with aqueous extracts, 62 patients were controls receiving only pharmacologic treatment.</td>
<td></td>
<td></td>
<td>SCIT treatment continued for 5 yrs. Follow-up at end of treatment.</td>
<td>SCIT group was subdivided into absorbed extracts and aqueous extracts because the latter was used more commonly than absorbed extracts at the beginning of the study.</td>
<td></td>
<td></td>
<td>SCIT was recommended to all patients. Those who rejected SCIT were included as controls. Children developing new sensitizations had higher atopy scores compared to those who did not develop new sensitizations. The same pattern was observed in the...</td>
</tr>
<tr>
<td>Age range: 6-16 yrs.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Marogna, 2010, Italy

| n=78 | Patients with allergic rhinitis with/without asthma lasting for at least 2 yrs and monosensitized to house dust mites. | Effect on development of new sensitizations and bronchial hyperreactivity. | SLIT for 3, 4 or 5 yrs. vs. pharmacotherapy. Build-up phase for approx. 50 days followed by SLIT 3 times a week in the maintenance phase. | AR, asthma, sensitized to house dust mites. | Low | New sensitizations occurred in all control subjects over 15 yrs. Among the SLIT group, 3/14 (21.4%) in the SLIT3 group, 2/16 (12.5%) in the SLIT4 group, and 2/17 (11.7%) in the SLIT5 group developed new sensitizations. Difference in occurrence of new sensitizations | The study design was prospective, open, controlled, 4 parallel-group, partially randomized. If patients refused SLIT, they were assigned to the control group. Assignment to groups was

57 in SLIT group subdivided into different length of SLIT (3 yrs: 19; 4 yrs: 21; 5 yrs: 17) 21 patients in control group. Adult patients (mean age of 22.2 +/- 5.2 yrs. at inclusion).
5 patients had transient oral itching during build-up phase, 2 patients reported 1 episode of generalized itching on maintenance. All adverse events occurred 30 min. after dosing and spontaneously disappeared.

Length of follow-up was 15 yrs. All dropouts were due to protocol deviations.

Adherence to SLIT greater than 80% measured by volume of extract in returned vials.

<table>
<thead>
<tr>
<th>Ohashi*, n=159</th>
<th>Patients</th>
<th>Effect on IT (unknown route)</th>
<th>Monosensitized to Unclear</th>
<th>Four years after Patients</th>
</tr>
</thead>
</table>

This article is protected by copyright. All rights reserved.
<table>
<thead>
<tr>
<th>Year</th>
<th>n</th>
<th>Study Description</th>
<th>Intervention</th>
<th>Outcome</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009, Japan</td>
<td>80 in mite immunotherapy group, 27 in house dust mite IT group, 52 in pharmacotherapy group. Age: &gt;20 yrs.</td>
<td>monosensitized to house dust mites.</td>
<td>development of new sensitizations for 4 yrs using a) D. farinae extracts (mite immunotherapy group) or b) house dust mite mixtures vs. pharmacotherapy.</td>
<td>mites.</td>
<td>Significantly lower incidence of new sensitizations in mite IT group compared to control group (p=0.0008), but no significant differences between HD IT group and controls (p=0.5999).</td>
</tr>
<tr>
<td>Ohashi, 2009, Japan</td>
<td>n=176, 194 in pollen immunotherapy group, 72 in pharmacotherapy group. Age: adult.</td>
<td>Patients monosensitized to Japanese cedar pollen.</td>
<td>Effect on development of new sensitizations IT (unknown route) for 4 yrs. vs. pharmacotherapy</td>
<td>Monosensitized to Japanese cedar pollen. Japanese cedar pollen.</td>
<td>Unclear</td>
</tr>
<tr>
<td>Authors</td>
<td>Pajno, 2001, Italy</td>
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<tr>
<td><strong>n=134 enrolled</strong></td>
<td><strong>75 patients in SCIT group, 63 children in control group</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>Children with intermittent asthma with/without new sensitizations</strong></td>
<td><strong>According to own rhinitis</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Age range: 5-8 yrs.</strong></td>
<td><strong>To house dust mite.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effect on development of sensitization</strong></td>
<td><strong>SCIT with mite mix was administered during the first three years in the intervention group. After induction phase, maintenance dose was administered once a month for 3 years.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Children with intermittent asthma with/without new sensitizations.</strong></td>
<td><strong>SCIT vs. pharmacotherapy.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>House dust mite.</strong></td>
<td><strong>AR, asthma.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td><strong>At the end of the 6-year study period, 52 (73.4%) patients in the SCIT group showed no new sensitizations compared to 18 (26.6%) in the control group (p=0.0002).</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>All patients had intermittent asthma at enrolment.</strong></td>
<td><strong>House dust mite.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>All patients conclude that SCIT may prevent onset of new sensitizations in children with intermittent asthma by mite immunotherapy but not by mite immunotherapy using other kinds of allergen extracts.</strong></td>
<td><strong>Authors conclude that new sensitization in allergic patients can be inhibited by mite immunotherapy but not by mite immunotherapy using other kinds of allergen extracts.</strong></td>
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<td></td>
</tr>
</tbody>
</table>
Patients with allergic rhinitis and/or asthma monosensitized to respiratory allergens. Patients in group A underwent SCIT with relevant allergens for 4 yrs. with an induction phase followed by maintenance injections at 4-week intervals. Low risk of new sensitizations in SCIT group (1706/7182, [23.75%]) compared to controls (826/1214, [68.03%]) after 4 yrs. of treatment. Effect of SCIT observed retrospectively.

SCIT was proposed to all patients. Those who accepted were parents instructed to decrease exposure to mites (e.g., by frequent vacuuming, washing sheets at least once a week, removal of plants/soft toys from bedroom). Both groups were followed for a total of 6 yrs.
Age range: >13 yrs old.

Three yrs. later, 1936/7182 (26.95%) among SCIT group and 932/1214 (76.77%) in control group had developed new sensitizations. Both comparisons were highly significant (p<0.0001).

Asthmatic patients, treated with SIT or not, were more prone to develop polysensitization compared to patients with rhinitis only.

Both groups were divided into subgroups according to presence of asthmatic symptoms at enrolment.

All patients were followed-up as outpatients in the period 1980-99.

Authors conclude that specific immunotherapy reduced new sensitization in monosensitized subjects.
Reha, 2007, Turkey

- n=107
- 56 patients in the SCIT group, 51 patients in the control group.
- Age range: 7-12 yrs.

Children with intermittent asthma sensitized to house dust mite or pollen species.

Effect on development of new sensitizations.

SCIT vs. pharmacotherapy.

Asthma, AR, monosensitization to grass pollen species or house dust mites.

House dust mite, grass.

Low

At 5 years follow-up, 35/43 (81.39%) of patients in house dust mite IT group and 10/13 (76.92%) patients in grass pollen IT group showed no new sensitizations. In the control group, 20/51 (53.84%) had developed new sensitizations. Difference between SIT groups and control group was statistically significant (p=0.033).

SCIT and control group were matched for age, asthma and/or AR severity, and respiratory function.

Authors conclude that SCIT appears to prevent development of new sensitizations.

Tella, 2003, Spain

- n=100
- 66 were treated with SCIT, 34 received

Patients with AR and/or asthma monosensitized.

Effect on development of new sensitizations.

SCIT vs. pharmacotherapy.

AR, asthma, monosensitization to grass pollen, Parietaria judaica pollen or Dermatophagoides

Low

No statistically significant differences in risk of developing new sensitizations between SCIT

Comparisons were made between

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<table>
<thead>
<tr>
<th>medication only.</th>
<th>was at least 3 yrs.</th>
<th>Grass pollen, Parietaria judaica, Dermatophagoides pteronyssinus, Dermatophagoides farinac.</th>
<th>group and controls (RR=0.97, 95% CI, 0.72-1.3). A total of 24/66 (36.4%) patients in the SCIT group had new sensitizations compared to 13/34 (38.2%) among controls.</th>
<th>baseline and after 3-5 yrs. of SCIT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age range: 6-69 yrs.</td>
<td></td>
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</tr>
</tbody>
</table>

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Table 3: Quality assessment of RCTs

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Design</th>
<th>Adequate sequence generation</th>
<th>Allocation concealment</th>
<th>Blinding patients/personnel</th>
<th>Blinding of outcome assessors</th>
<th>Incomplete outcome data addressed</th>
<th>Free of selecting reporting</th>
<th>Free of other bias*</th>
<th>Overall quality assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimi, 2004</td>
<td>RCT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Medium</td>
</tr>
<tr>
<td>Dominicus, 2012</td>
<td>RCT</td>
<td>Unclear</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Unclear</td>
<td>No</td>
<td>No</td>
<td>Low</td>
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<tr>
<td>Garcia, 2010</td>
<td>RCT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Grembiale, 2000</td>
<td>RCT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Holt, 2013</td>
<td>RCT</td>
<td>Unclear</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Medium</td>
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<tr>
<td>Jacobsen, 2007</td>
<td>RCT</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<td>Low</td>
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<tr>
<td>Limb, 2006</td>
<td>RCT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
<td>No</td>
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<tr>
<td>Marogna, 2004</td>
<td>RCT</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<td>Marogna, 2008</td>
<td>RCT</td>
<td>Unclear</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<td>No</td>
<td>Low</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Randomisation</th>
<th>Allocation</th>
<th>Masking</th>
<th>Blinding</th>
<th>Attrition</th>
<th>Publication Bias</th>
<th>Quality</th>
</tr>
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<tbody>
<tr>
<td>Möller, 1986</td>
<td>RCT</td>
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<tr>
<td>Novembre, 2004</td>
<td>RCT</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Pifferi, 2002</td>
<td>RCT</td>
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<td>Unclear</td>
<td>Unclear</td>
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<td>No</td>
<td>Yes</td>
<td>Medium</td>
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<tr>
<td>Song, 2014</td>
<td>RCT</td>
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<td>No</td>
<td>Unclear</td>
<td>Unclear</td>
<td>No</td>
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<td>Low</td>
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<tr>
<td>Szepfalusi, 2014</td>
<td>RCT</td>
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<td>Yes</td>
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<td>High</td>
</tr>
<tr>
<td>Valovirta, 2016</td>
<td>RCT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>High</td>
</tr>
<tr>
<td>Yamanaka, 2014</td>
<td>RCT</td>
<td>No</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Unclear</td>
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<td>Low</td>
</tr>
<tr>
<td>Zolkipli, 2015</td>
<td>RCT</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>High</td>
</tr>
</tbody>
</table>
### Table 4: Quality assessment of CBAs

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Design</th>
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<th>Blinding of outcome assessors</th>
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Table 5: List of excluded studies with reasons for exclusion

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<tr>
<th>Reference</th>
<th>Incorrect study design</th>
<th>Incorrect outcome</th>
<th>Incorrect intervention</th>
<th>Other</th>
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<tr>
<td>Bousquet J. Sublingual immunotherapy: from proven prevention to putative rapid relief of allergic symptoms. Allergy 2005; 60:1-3.</td>
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<td>Name</td>
<td>Title</td>
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<td>Iu AP, Rybchinskaia LM, Chervinskaia TA, Titova SM</td>
<td>[Effectiveness of specific prevention of pollinoses and dust-induced bronchial asthma].</td>
<td>Terapevtitcheskii Arkhiv</td>
<td>1981</td>
<td>53:94-8</td>
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<tr>
<th>Author(s)</th>
<th>Reference</th>
<th>Status</th>
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<td>Marogna M, Massolo A, Berra D, Zanon P, Chiodini E, Canonica GW, Passalacqua G.</td>
<td>The type of sensitizing allergen can affect the evolution of</td>
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<table>
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<th>Title and Details</th>
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<tr>
<td>Mener DJ, Lin SY</td>
<td>AAOA asthma primer: improvement and prevention of asthma with concomitant treatment of allergic rhinitis and allergen-specific therapy. Int Forum Allergy Rhinol 2015/6; 5 Suppl 1:45.</td>
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<td>Study</td>
<td>Details</td>
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<td>-------</td>
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Appendix 1: Search strategy

Search strategy 1

(MEDLINE, EMBASE)

1. exp Primary prevention/
2. Primary prevention.mp.
3. exp Secondary prevention/
5. exp Tertiary prevention/
7. Prevention.mp.
8. Etiology.mp.
10. (“risk of developing” or “risk for development”).mp.
11. (effect* or cause* or protect* or risk*).mp.
12. or/1-11
13. exp Desensitization, Immunologic/
14. exp Immunotherapy/
15. Desensitization.mp.
17. Allergy vaccination.mp.
18. (Immunotherapy or allergen immunotherapy).mp.
19. Subcutaneous immunotherapy.mp.
20. Epicutaneous immunotherapy.mp.
21. Intradermal immunotherapy.mp.
22. Sublingual immunotherapy.mp.
23. Oral Immunotherapy.mp.
25. Specific oral tolerance induction.mp.
27. Intranasal immunotherapy.mp.
29. Intralymphatic immunotherapy.mp.
30. Specific immunotherapy.mp.
31. Or/13-30
32. exp Intervention Studies/
33. Intervention studies.mp.
34. exp Clinical Trial/
35. trial.mp.
36. Clinical trial.mp.
37. exp Controlled Clinical Trial/
38. Controlled Clinical Trial.mp.
39. Randomized Controlled Trial.mp.
40. Quasi-randomized trial.mp.
41. Non-randomized trial.mp.
42. exp Placebos/
43. Placebos.mp.
44. exp Random allocation.mp.
45. Random allocation.mp.
46. exp Double-blind method/
47. Double-blind method.mp.
48. Double-blind design.mp.
49. exp single-blind method/
51. Single-blind design.mp.
52. Triple-blind method.mp.
54. (Controlled before and after stud*).mp.
55. Interrupted Time Series Analysis/ or interrupted time series.mp.
56. Search:.tw.
58. Systematic review.tw.
60. Case series.mp.
61. (Case$ and series).tw.
62. Cost:.mp.
63. Cost effective:.mp.
64. Cost utility:.mp.
65. Exp Health care Costs/
66. (Costs and Costs Analysis).mp.
68. ((cost effective* adj1 analys*) or cost minimi?ation analys* or cost benefit analys* or cost utility analys* or cost consequence analys* or finances).mp.
69. Or/32-68
70. 12 and 31 and 69

Search strategy 2
(Cochrane library, HTA, EED, CINAHL, ISI Web of Science, TRIP)

(Prevention or “primary prevention” or secondary prevention” or “tertiary prevention” or etiology or “risk of developing” or “risk for development” or effect* or cause* or protect* or risk)

AND
(Immunologic, desensiti* or hyposensitization or immunotherapy or allergen immunotherapy or specific immunotherapy or allergen specific immunotherapy or allergy vaccination or subcutaneous immunotherapy or epicutaneous immunotherapy or intradermal immunotherapy or sublingual immunotherapy or oral immunotherapy or oral desensitization or specific oral tolerance induction or oral tolerance induction or intranasal immunotherapy or bronchial immunotherapy or intralymphatic immunotherapy)

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APPENDIX 2: EXPERTS CONSULTED

1. Lars Jacobsen, Denmark
2. Eva Maria Varga, Austria
3. Erkka Valovirta, Finland
4. Peter Eng, Switzerland
5. Ojedo, Pedro, Spain

APPENDIX 3: PRISMA CHECKLIST

<table>
<thead>
<tr>
<th>Section/topic</th>
<th>#</th>
<th>Checklist item</th>
</tr>
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<tr>
<td>TITLE</td>
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<td><strong>Checklist item</strong></td>
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<tr>
<td>Title</td>
<td>1</td>
<td>Identify the report as a systematic review, meta-analysis, or both.</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>2</td>
<td>Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td></td>
<td></td>
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<tr>
<td>Rationale</td>
<td>3</td>
<td>Describe the rationale for the review in the context of what is already known.</td>
</tr>
<tr>
<td>Objectives</td>
<td>4</td>
<td>Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).</td>
</tr>
<tr>
<td>METHODS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protocol and registration</td>
<td>5</td>
<td>Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.</td>
</tr>
<tr>
<td>Eligibility criteria</td>
<td>6</td>
<td>Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.</td>
</tr>
<tr>
<td>Information sources</td>
<td>7</td>
<td>Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.</td>
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</tbody>
</table>

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<table>
<thead>
<tr>
<th>Section/topic</th>
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<th>Checklist item</th>
<th>Reported on page #</th>
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<tbody>
<tr>
<td>Risk of bias across studies</td>
<td>15</td>
<td>Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).</td>
<td>7-8</td>
</tr>
<tr>
<td>Additional analyses</td>
<td>16</td>
<td>Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.</td>
<td>7-8</td>
</tr>
<tr>
<td>RESULTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study selection</td>
<td>17</td>
<td>Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.</td>
<td>8, 31</td>
</tr>
<tr>
<td>Study characteristics</td>
<td>18</td>
<td>For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.</td>
<td>8-21, 37-56</td>
</tr>
<tr>
<td>Risk of bias within studies</td>
<td>19</td>
<td>Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).</td>
<td>8-21, 58-59</td>
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<tr>
<td>Results of individual studies</td>
<td>20</td>
<td>For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.</td>
<td>8-21, 37-56</td>
</tr>
<tr>
<td>Synthesis of results</td>
<td>21</td>
<td>Present results of each meta-analysis done, including confidence intervals and measures of consistency.</td>
<td>11-14, 16-17, 19, 32-36</td>
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<tr>
<td>Risk of bias across studies</td>
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<td>Present results of any assessment of risk of bias across studies (see Item 15).</td>
<td>11-13, 16-17, 19, 32-36</td>
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<tr>
<td>Additional analysis</td>
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<td>Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).</td>
<td>11-14, 16-17, 19, 32-36</td>
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<td>DISCUSSION</td>
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<td>Summary of evidence</td>
<td>24</td>
<td>Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).</td>
<td>21-22</td>
</tr>
<tr>
<td>Limitations</td>
<td>25</td>
<td>Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).</td>
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</table>
### Conclusions

26 Provide a general interpretation of the results in the context of other evidence, and implications for future research.

### FUNDING

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<tr>
<th>Funding</th>
<th>27 Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.</th>
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