

# Does Allergen Avoidance Work?

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## KEYWORDS

- Allergic rhinitis • Allergen avoidance • Indoor allergens
- Polysensitization

Ten percent to 25% of individuals globally are sensitized to allergens.<sup>1</sup> In the United States, it is estimated that 30 to 60 million persons are affected by allergic rhinitis.<sup>2</sup> The National Health and Nutrition Examination Survey (NHANES) III study from the United States indicated that 25.7% of individuals in this large cohort were sensitive to house dust mite, 26% to cockroach, and 17% to cat allergen.<sup>3</sup> Because individuals are exposed to indoor allergens throughout the year, allergic rhinitis owing to sensitization to these allergens tends to be perennial.

Exposure to indoor allergens is widespread. Surveys conducted in the United States showed that more than 80% of homes and 85% of day care facilities have detectable dust mite allergen levels.<sup>4</sup> In addition, pet allergens from dogs and cats are detected in most US homes, even where there has never been an animal.<sup>5</sup> Similarly, pet allergens have been detected in schools as well. Recent studies have indicated that in US housing, dust mites, cockroaches, cats, dogs, and mice are important contributors to indoor allergen levels.<sup>6</sup> Water leaks, visible mold growth, poor housekeeping, and homes constructed before 1951 contribute to these increased allergen concentrations in the indoor environment.<sup>6</sup> Thus, allergic rhinitis is a common condition, it is often a result of sensitization to indoor allergens, and exposure in indoor environments is frequent.

Genetics also play an important role in the development of sensitization to allergens and to allergic respiratory disease. It is well known that strong family history increases the likelihood that a child born of an atopic parent is likely to become sensitized and eventually develop allergic respiratory disease. Interestingly, gender differences may have an effect on allergen exposure and disease expression. Bertelsen and colleagues<sup>7</sup> found that girls had higher exposure levels to cat and dog allergens than boys, whereas no differences were found in dust mite allergen exposure between boys and girls. However, increased levels of exposure to house dust mite allergen significantly increased the risk of a diagnosis of current allergic rhinitis in girls, whereas there was no significant association found in boys.<sup>7</sup> In addition to the affects of

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genetics on the risk of immunoglobulin (Ig) E antibody productions to allergen, the environment can also interplay with genetic processes known as epigenetics. Indoor exposures to tobacco smoke, microbial allergens, airborne particulate matter, diesel exhaust particles, nutritional factors, and other exposures may affect DNA methylation, alter histone modifications, affect specific micro RNA expression, and other alterations that orchestrate the immune responses, which may lead to allergic diseases.<sup>8</sup> Although specific allergen sensitization is generally thought not to be directly inherited, recent data suggest that sensitization to specific allergens in the parents increases the likelihood of sensitization to same allergen in their offspring.<sup>9</sup> This may not indicate the specific sensitization is genetically determined, but the risk factors for the development of sensitization and similar exposures between parent and the early life of the child are likely, and this may account for this observation.

It is well known that sensitization (ie, development of specific IgE antigens to a specific allergen) occurs early in life. At most time points, boys are significantly more likely to be sensitized and sensitization increases from childhood and into adolescence. Among the first sensitivities to develop is to house dust mites, because exposure to these allergens are ubiquitous in bedding and in most homes. Although controversial, early exposure to animal allergens from cats and dogs may actually provide some protective effect on the development of sensitization (to these allergens).<sup>10</sup>

The affects of allergen exposure can influence epigenetics, as mentioned previously. Moreover, various exposures can act as adjuvants to the generation of IgE responses. Chitin particles, which arise from fungi, insects, and other allergens, can act as T helper cell 2 (Th2) adjuvants to increase specific allergen sensitization.<sup>11</sup> Ingress into the indoor environment of various pollutants, such as diesel exhaust particles, may also enhance IgE production.<sup>12</sup> In addition, it is well known that endotoxin may influence Th2 expression and can, in and of itself, act as a respiratory irritant.<sup>13</sup> Proteases from sources such as fungi, dust mites, and other sources, have also been shown to affect eosinophilic inflammation and other factors can influence the innate immune system that bias Th2 responses.<sup>14</sup>

In conclusion, allergen exposure, as well as other exposures in the indoor environment, contribute to the pathophysiology and generation of allergic sensitization and allergic inflammation. Therefore, indoor allergen exposure plays a central role in the development of allergic rhinitis and must be addressed in any comprehensive management plan.

## **BIOLOGY AND CHARACTERIZATION OF INDOOR ALLERGENS**

### ***House Dust Mite***

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In most humid areas of the world, house dust mites are the major source of allergens in house dust.<sup>15</sup> Dust mites are microscopic arthropods that feed on human skin scales. They depend on water from the ambient air. Typically, house dust mites are found in abundance where indoor relative humidity is higher than 50%. High altitude and cold dry air inhibit dust mite proliferation. There may be some seasonal fluctuation in indoor house dust mite allergen levels because indoor humidity is typically higher in summer months than in winter months in the United States. In the home, mites are found in fabrics, such as mattresses, pillows, stuffed animals, upholstered furniture, and carpeted floors and rugs. Higher concentrations are found in older homes where there is high humidity and heating other than forced air systems are used. Mite bodies and fecal pellets are the major sources of allergens, which become airborne when disturbed.<sup>16</sup> Because of the aerodynamic features of the particles, which are 10  $\mu\text{m}$

or larger in diameter, they remain suspended in the air for a relatively short period of time, which prevents air filtration from being an effective measure to reduce airborne levels. The most commonly encountered house dust mites are *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*. In tropical areas, *Blomia tropicalis* predominates. Storage mites may also be important indoor allergens in areas such as farms, where grain and other sources of food for these arthropods are available. To date, approximately 22 to 23 different house dust mite allergens have been identified.<sup>17</sup> IgE responses to house dust mite allergen occur early in life.<sup>18</sup> Sensitization may rarely remit. Approximately 3% of children followed over 18 years show a decrease in IgE response to dust mite.<sup>19</sup> The IgE response to dust mites typically contributes significantly to the total IgE level and there is little evidence that tolerance or IgG<sub>4</sub> responses occur.<sup>20</sup>

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### Cats

Pets are a major cause of indoor sensitization and contribute to allergic rhinitis. However, in contrast to house dust mite allergens, cat allergens are distributed on both large aerodynamic and smaller particles, which tend to remain airborne for longer periods of time and thus are amenable to air filtration. The cat allergens are produced in sebaceous glands of the cat and are present on the skin and fur. The major allergen is found in the salivary gland, and additional allergens are added to the hair when the animals groom themselves.<sup>21</sup> Because of electrostatic charges, cat allergens can stick to surfaces such as walls.<sup>22</sup> The major cat allergen (*Fel d 1*) is under androgenic hormonal control and is, therefore, produced in higher concentrations by male cats than female cats. In contrast to dust mite allergens, exposure to cat allergens, especially at high levels, may induce IgG<sub>4</sub> immune responses, which may reduce the risk of the development of allergic disease.<sup>23</sup> However, this phenomenon is dependent on high exposure levels.<sup>24</sup> Because cat allergen is distributed outside the home, allergen avoidance in the home alone may not be of particular value in diminishing sensitization,<sup>25</sup> because cat allergens are found in 90% of all homes and in most public indoor areas (even those without pets).<sup>26</sup>

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### Dogs

Exposure to cat and dog allergens is common, as 56% to 63% of US households have indoor pets.<sup>26</sup>

The major dog allergens have been shown to have physical properties similar to cat allergens, and there may be a synergistic effect between exposure to cats and dogs in the home that results in a lowered risk for the development of atopy in childhood and young adulthood.<sup>27</sup>

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### Mouse Allergens

Sampling in residential homes in the United States indicates that 82% have detectable levels of mouse allergen.<sup>28</sup> Some geographic areas, such as inner-city dwellings, have high levels of mouse allergen, and subsequently it has been shown that 25% of inner-city children have evidence of IgE sensitivity to mouse.<sup>29</sup> Socioeconomic conditions may not be of potential importance in women sensitized to mouse allergen, as shown in a recent report.<sup>30</sup>

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### Cockroaches

Cockroach allergens are an important factor in allergic sensitization, particularly in children in inner-city environments.<sup>31</sup> The major species of cockroaches are *Blattella germanica* (German cockroach) and *Periplaneta americana* (American cockroach). At

least 9 to 10 cockroach allergens have been described.<sup>17</sup> Seasonal variations in exposure may occur, with higher levels of exposure occurring during the summer and fall months.<sup>32</sup>

### ***Other Insect Allergens***

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In addition to cockroaches, seasonal indoor allergen symptoms may be attributable to a newly identified insect allergen, the Asian lady beetle (*Harmonia axyridis*).<sup>33</sup> Cross-reactivity between German cockroach and Asian lady beetle allergens has recently been reported.<sup>34</sup>

### ***Fungi***

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Fungi, or molds, are widely distributed throughout the world. These organisms are found in most temperate climates globally. The optimal conditions for growth vary among species but all require oxygen, a carbon source, and water. Typically, fungi are found where water leaks or standing water is found in the indoor environment. These organisms are often detected by visible mold growth or by a “musty” or “mildew” odor. Sensitization to fungi, such as *Alternaria*, is strongly associated with allergic rhinitis in children.<sup>35</sup> Many homes have high levels of fungal allergens detectable in the indoor environment. However, in contrast, others have found that outdoor fungal exposure may be more important in causing allergic symptoms than indoor exposures.<sup>36</sup> Fungal exposure in the indoor environment may result from 1 of 2 routes: intrusion from the outdoor environment or growth within the indoor environment. These can be ascertained by conducting studies on both the indoor and the outdoor environment simultaneously, and if the indoor environment shows a higher level of fungal propagals by culture (spore counts) it can be assumed that the exposure is the result of indoor contamination.

### ***Pollen Intrusion***

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Last, pollens can intrude from the exterior into the interior environment from open windows, cracks, and so forth. Thus, during seasonal pollination of plants, indoor exposures can occur, although outdoor exposure is the primary route. Further, in addition to intrusion through outdoor sources, pollens may also enter through clothing<sup>37</sup> and are occasionally carried in on the fur of pets, but the overall contribution of this exposure appears to be relatively small, and its overall role is unknown.

### ***Effects of Climate Change***

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The indoor environment is an important source of allergen exposure. Concerns have arisen regarding the effect of climate change on allergic disease.<sup>38</sup> The effect of global climate change may have dramatic effects on the indoor as well as the outdoor environment, where it has been studied more carefully. Future research is needed in this regard.

### ***Molecular Biology of Indoor Allergens***

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Molecular biology developments over the past 2 decades have led to a better understanding of allergic sensitization and disease processes. The molecular cloning of a number of allergenic proteins has shed light on their structure and biologic functions. There are more than 23 known dust mite allergens identified to date,<sup>17</sup> several of which have enzymatic activity, that can either act as adjuvants to enhance IgE production or increase penetration of allergens through epithelial barriers. Reviews of the characteristics of allergens can be found in Chapman and colleagues<sup>39</sup> and Radauer and colleagues.<sup>40</sup>

At least 7 allergens have been identified in cats and dogs.<sup>17</sup> *Fel d 1* is the major cat allergen, and *Canis familiaris* allergen 1 (*Can f 1*) and *Can f 2* are important dog allergens. Recently, a carbohydrate, galactose- $\alpha$ -1,3-galactose has been shown to be the major IgE-binding epitope on cat IgA, which is a minor allergen.<sup>41</sup> This allergen has been shown to be cross-reactive in patients with food allergy to nonprimate mammalian species. In addition, serum albumins of furred animals may also play a role in some cases of allergy to furred animals.<sup>42</sup>

Of the cockroach allergens, 9 to 10 different allergens have been identified.<sup>17</sup> The major cockroach allergen, *Bla g 2*, has been the most extensively studied. Although characterized as an enzyme, based on its protein structure, it is not known to possess any active enzymatic activity.

A number of fungal allergens have been identified in the indoor environment. Several species are considered to be more likely to be indoor than outdoor allergens. The main species involved are *Penicillium* and *Aspergillus*; however, a number of fungal species can be found in the indoor environment based on substrate and humidity factors. *Alternaria* antigens have been detected in many US homes.<sup>43</sup> At least 9 *Alternaria* allergens have been characterized.<sup>17</sup> The most important of these is *Alt a 1*, which is the major allergen. *Penicillium* and *Aspergillus* species often have cross-reactive allergens, some 34 to 35 allergens from both *Penicillium* species and *Aspergillus fumigatus* have been identified.<sup>17</sup> Many of these have proteolytic activity and, therefore, may act as adjuvants in Th2-driven mechanisms.

## DIAGNOSIS OF INDOOR ALLERGEN SENSITIZATION

It is clear that self-reported histories of allergic rhinitis symptoms alone are only modest predictors of true sensitization.<sup>44</sup> Testing for the presence of IgE sensitization by either skin test or in vitro assay is necessary to establish the correct diagnosis.

The assessment of allergic status and true diagnosis cannot be based on history alone but requires additional supporting data, such as a positive skin-prick test.<sup>45</sup> Because symptoms of dust mite and cockroach sensitivity, for example, are perennial, the diagnosis can be achieved only by appropriate testing. The molecular biology of allergens has improved diagnostic capabilities. Microarray techniques,<sup>46</sup> in which specific molecules produced recombinantly are displayed on a microarray and subsequently probed with serum from a patient with suspected sensitization, can improve clinical diagnosis and are very helpful in epidemiologic studies of allergic disease.

### The Importance of Polysensitization

Polysensitization to indoor as well as outdoor allergens in the development of allergic rhinitis has been demonstrated in several studies.<sup>47,48</sup> Although sensitization appears to decrease with age, 40% or more of individuals older than 60 years have been shown to have sensitization to one or more indoor allergens.<sup>49</sup> It would, therefore, seem appropriate to conduct skin testing or in vitro assays for specific IgE sensitization in patients presenting for evaluation of chronic rhinitis symptoms so that allergen avoidance measures can be tailored to the patient's specific sensitivities.

## ASSESSMENT OF INDOOR ENVIRONMENTAL EXPOSURE

Attempts have been made to establish a threshold of allergen exposure levels that are associated with sensitization and subsequent allergic disease. Such attempts have proven challenging because exposures in the indoor environment are complex and the relationships between exposure and sensitization and/or symptoms in particular are nonlinear.<sup>50,51</sup> Nonetheless, techniques for environmental sampling have been

developed to measure specific allergens via the use of monoclonal antibody-based immunoassays. The major source of house dust mite exposure is in bedding and carpeting, as mentioned previously. Settled dust samples are collected by vacuuming bedding or floors using specific protocols, and the concentration of a major dust mite allergen can be measured through the use of immunoassays, which are commercially available (for example, Indoor Biotechnologies, Charlottesville, VA, USA). Such sampling techniques have been useful in ascertaining the concentration of the major allergen, as well as evidence for exposure reduction in outcome studies.

Similarly, for the major cat allergen, settled dust samples can be assayed; however, airborne samples using air-sampling technology can also be adapted to detect the major cat allergen, *Fel d 1*. Fewer studies have been conducted with major dog allergen. There are several reports of the use of immunoassays for assaying mouse allergens in the indoor environment.

Assessing exposure to fungal allergens has proven more problematic. Although one study used polyclonal antibodies to detect *Alternaria* allergens in indoor environments,<sup>43</sup> few studies have used monoclonal antibody-based immunoassays. Most often, fungal allergen presence is performed by quantitative culturing techniques of air samples or by spore counts,<sup>52</sup> as exposure can originate from outdoor intrusion of fungal spores or from an indoor source. Simultaneous tests need to be conducted on both indoor and outdoor samples to determine whether an indoor source is present. A guide to interpretation of indoor fungal spore assessments has been published.<sup>53</sup>

As with in vitro diagnostic tests for IgE sensitization, molecular biology has advanced the technology for assessing exposure to indoor allergens. Using a microarray assay system, a number of indoor allergens (*Der p 1*, *p 2*, *f 1*, *f 2*, *Fel d 1*, and *Can f 1*) can be analyzed in a single settled dust sample.<sup>54</sup> Further investigations that will expand the capabilities of these multiplex assay systems are ongoing.

## ALLERGEN AVOIDANCE MEASURES

Although it seems intuitive that avoidance of allergen exposure should lead to improvement in allergic rhinitis symptoms, this has been difficult to achieve, particularly in home environments. It is well known that when seasonal pollen allergen exposures cease, symptoms abate shortly thereafter. Likewise, in occupational asthma, removal from exposures tends to improve symptoms as well. Evidence that allergen avoidance is beneficial has been verified in several studies. It should be pointed out that many of the studies involved in allergen avoidance are aimed at asthma, as opposed to rhinitis. The key to success is that exposure levels have to be reduced to near negligible amounts to achieve a positive effect. Use of settled dust or airborne samples for concentrations of major indoor allergens, as discussed previously, can be used as a marker for effective allergen exposure reduction. However, indoor environments contain complex mixtures of allergens and other factors that can affect symptoms of allergic rhinitis. The complexity and nonlinearity of dose response relationships also makes such evaluations of the effectiveness of allergen avoidance difficult.

In one of the earliest allergen avoidance studies, Platts-Mills and colleagues<sup>55</sup> demonstrated that putting patients who are allergic to dust mites in a hospital room for 2 months or more (where the exposure to house dust mite was negligible) resulted in improvement in symptoms and medication use. Further investigations have been conducted at high altitude, where house dust mite concentrations tend to be low as a result of the low humidity and colder temperatures.<sup>56,57</sup> These studies showed beneficial effects on airway inflammation symptoms and other markers of allergic disease.

Using a multifaceted approach in children with asthma with multiple indoor allergen exposures, including such interventions as using impermeable encasements for the mattress and pillows, vacuuming with a HEPA-filtered vacuum, and using a HEPA air purifier, had modest benefits on their symptoms.<sup>58</sup> However, interventions for control of house dust mite avoidance in subjects with asthma, when examined by meta-analyses, demonstrated that chemical and physical methods aimed at reducing exposure to house dust mite allergens cannot be recommended.<sup>59</sup> These and other meta-analyses have come under some criticism because of inclusion and exclusion criteria used in the evaluation.<sup>60</sup>

Because there is some evidence to support strict allergen avoidance, strategies that optimize the reduction of allergen exposure in homes have not been fully determined. There are complex issues regarding the efficacy of measures that target a variety of allergens in the home. One approach that may be particularly useful is educating patients or their caregivers so that they may intervene and perhaps lead to more successful outcomes.<sup>61</sup>

Nonetheless, allergen control measures, although difficult, should be an integral part of the overall management of sensitized patients. Which interventions are the most cost effective remains to be determined, and further trials are warranted.<sup>62</sup>

### House Dust Mites

Specific recommendations for reducing house dust mite exposure are shown in **Box 1**. These include fitting of allergen-proof mattress, pillow, and box spring encasements, washing bedding regularly in hot water, and possibly by reducing indoor humidity. Acaricides designed to kill dust mites in carpets have, in and of themselves, proved largely ineffective because the mite populations return shortly after their application, and they may also cause skin and respiratory irritation. Pillow, mattress, and box spring encasements are often used as a single approach to house dust mite allergen avoidance. Randomized controlled trials of such encasements did not seem to provide any benefit in mite-sensitized adults.<sup>63</sup> However, encasements as part of a comprehensive approach can be effective.<sup>64</sup> If such encasements are to be used,

#### Box 1

##### House dust mite allergen avoidance measures<sup>a</sup>

###### *Primary focus: Bedroom*

- Use dust mite impermeable pillow and encasements (woven preferable to nonwoven material). Encase box springs.
- Wash bedclothes in hot water (130°F) weekly. Dry on hot cycle.

###### *Long-term:*

- Maintain indoor relative humidity  $\leq 50\%$  (dehumidifiers, air conditioning)
- Minimize wall-to-wall carpets
- Minimize draperies
- Minimize upholstered furniture
- Avoid carpets on cement slabs (eg, basement floors). Condensation under carpet provides moisture conducive to mite proliferation.
- Vacuum with double-layer vacuum bag

<sup>a</sup> To be effective, measures must reduce HDM allergen levels to  $<0.5 \mu\text{g/g}$  of settled dust.

a woven mattress encasement is preferred because nonwoven materials can actually accumulate mite and cat allergens.<sup>65</sup> Washing bed clothing in hot water has been shown to kill dust mites and washing is necessary to remove allergens from the bedclothes. Alternatively, freezing conditions also will kill dust mites; therefore, stuffed animals may be placed in a plastic bag in a freezer and then, if possible, washed to remove any remaining allergen. Likewise, hanging rugs outside in freezing conditions may also kill dust mites, but a thorough cleaning is then necessary. Reduction in humidity with improved ventilation control may have little effect on house dust mite allergen levels; however, some minor improvement in respiratory outcomes can be demonstrated.<sup>66</sup> The use of impermeable casings, which can cost up to several hundred dollars, is one of the limiting factors in their use in patients with symptomatic allergic disease. In a recent study, it was shown that in patients receiving immunotherapy, few if any were practicing dust mite avoidance measures.<sup>67</sup> Nonetheless, the studies on dust mite allergen avoidance as a preventive and therapeutic strategy indicate that such stringent measures may reduce potential sensitization<sup>68</sup> but there is little evidence to support the use of single approaches, such as mite-proof encasements, as an intervention in adults for symptomatic control. In children, however, single or multiple-faceted interventions may have some benefit.<sup>68</sup>

### Pets

For individuals sensitized to pet allergens (**Box 2**), removal of the pet from the home is the most useful technique, although this has not been studied in any systematic way. Many pet owners, however, are unlikely to relinquish the pet. It should be borne in mind that cat allergen levels can persist for longer than 6 weeks once the pet has been removed. Washing walls and other washable surfaces may be helpful in reducing allergen exposure once the pet has been removed.<sup>22</sup> Efforts have been made to reduce allergen exposure with the animal in situ. Such measures include the use of HEPA filters,<sup>69</sup> and although HEPA filters can reduce the airborne cat allergen concentration, their use does not improve allergen-related symptoms. Other measures include use of HEPA-filtered vacuum cleaners and washing the cat. Although these also have been shown to reduce allergen levels, improvement in symptoms has not been addressed. Likewise, a combination of mattress encasements and cat exclusion from the bedroom reduced airborne cat allergen levels, but no effect on disease activity was detected.<sup>70</sup> A Cochrane analysis of the available data suggests that the

#### Box 2

##### Animal dander allergen avoidance measures

*Focus: Remove pet(s) from environment*

- Find suitable alternative home for pet
- Thorough cleaning after pet removed<sup>a</sup>

*Measures to reduce exposure with pet in situ are NOT effective.*

- Washing pet
- Confining pet to certain areas in home
- Vacuuming with HEPA filter vacuum
- HEPA air filtration

<sup>a</sup> May require 6 months for allergen levels to decline.

studies are too small to provide evidence for or against the use of air-filtration units in the management of pet allergy.<sup>71</sup>

### **Cockroaches and Other Pests**

Particularly in inner-city environments, cockroach allergen (**Box 3**) is a major sensitizer and cause of allergic symptoms. Approaches include pesticides; sanitation, such as making sure that there is no food available to the cockroaches; control of water leaks; and control of entrances. An integrated pest-management program that involves sanitation building management and limited use of pesticides has been helpful in reducing allergen exposure.<sup>72</sup> Once cockroaches have been eliminated from the environment, a thorough cleaning is necessary, not only immediately after pesticide treatment, but continued for long periods of time (up to several months) to remove the allergen.

Likewise, mouse exposure, particularly in bedrooms, is prevalent, especially in inner-city dwellings. Methods for effective rodent control have been shown to reduce allergen exposure and improvement in patient activities.<sup>73</sup>

### **Fungi**

The role of fungal allergen avoidance (**Box 4**) in respiratory disease has had limited investigation.<sup>74</sup> Most instances of fungal growth in the indoor environment are caused by moisture issues (leaks, condensation, and other causes for water accumulation). Repair of any water leaks and humidity control are key factors that can be used. Control of the indoor environmental humidity with reductions to below 50% relative humidity has been recommended.<sup>52</sup> Contaminated materials that can be discarded should be removed. Surfaces that can be washed should be treated with dilute 5% bleach solution with a detergent.<sup>52</sup> A study of the use of hypochlorite bleach solutions to reduce exposure demonstrated that there was a reduction in sensitization to cat and overall sensitization<sup>75</sup>; however, fungal allergen sensitization was not studied.

#### **Box 3**

##### **Cockroach allergen avoidance measures**

*Focus: Integrated pest management program (professional pest control)*

- Thorough cleaning of infested areas
  - Mopping floors
  - Washing counter tops and appliances with detergent, water-dilute bleach
  - Vacuuming
- Seal portals of entry
  - Wall cracks, and so forth
- Remove food sources
  - Clean up spills
  - Keep sinks clear of dirty dishes
- Remove water sources
  - Repair leaks, and so forth
- Wash bedclothes
- ? Mattress, pillow encasements
- ? HEPA air filters

**Box 4****Indoor fungal allergen avoidance measures<sup>a</sup>***Focus: Remove moisture sources*

- Repair leaks
- Remove standing water, eg, humidifiers
- Maintain indoor relative humidity  $\leq 50\%$  with dehumidifiers, air conditioning
- Remove contaminated materials—clothing, books, carpets, and so forth
- Wash washable surfaces with 5% chlorine bleach–water solution containing a detergent
- Proper HVAC (heating, air conditioning) system maintenance
- ? Use of HEPA air filtration

<sup>a</sup> All recommendations are empiric.

Such remediation efforts can reduce spore counts; however, the effectiveness of this in the overall management of allergic disease attributable to fungal sensitization is not clear. Air filtration and air cleaners may also reduce concentrations of fungal spores and indoor pollen in theory. A recent review has been conducted regarding the use of these systems.<sup>76</sup>

Most allergen avoidance approaches are directed at reducing symptoms in patients with established sensitivities. Any approach to allergen avoidance needs to be targeted at the allergen to which the patient is sensitized; therefore, appropriate skin testing or in vitro testing for specific sensitivities is necessary before recommending any environmental control measures that have some costs associated with them.

Alternatively, environmental controls can be directed toward the prevention of allergic sensitization. Studies are under way<sup>77</sup> in which pregnant women at risk for having children who will develop allergic disease are instructed in specific avoidance measures. These studies are designed to determine if control measures are effective in preventing allergic sensitization in the infants. Substantial reductions in levels of major house dust mite, as well as pet allergen concentrations, have been demonstrated in these environments, but the long-term outcomes are not known. Among the difficulties with this type of approach is that not only are allergens reduced, but other environmental factors that influence the outcome are also affected. Consequently, studies that look at genetics as well as the environment and their interactions are important in future investigations.

Education plays an important role in allergen avoidance strategies. One study<sup>78</sup> demonstrated that intensive education of patients at risk for developing allergic disease were able to reduce exposures, but this also occurred in a control group as well. There was a slight reduction in incidence of respiratory symptoms in the group that achieved some measure of environmental control. Environmental control practices were more likely to be instituted by the caregivers of children with allergic rhinitis symptoms than those who had asthma.<sup>79</sup> Applying allergen avoidance measures in the treatment of children who live in poverty is difficult because of the multiple sensitivities and problems with applying protocols, often because of cost concerns. However, home visiting by professionals demonstrates positive influences on management of such patients. In addition to the study by Morgan and colleagues,<sup>58</sup> a tailored, multifaceted environmental program designed to reduce airborne indoor allergen levels as well as airborne particulates in inner-city homes had some modest effects on symptoms.<sup>80</sup> For patients who have poorly controlled respiratory disease,

home intervention by nurses or other professionals could improve outcomes.<sup>81,82</sup> Such visits can identify ways of improving the home environment. A more recent study indicates that home environmental assessment and case management through environmental education and assessments may improve outcomes for allergic rhinitis and reduce emergency room visits for asthma.<sup>82</sup>

Because of the complexities of the indoor environment, single interventions in comparison with combined strategies may not be effective.<sup>83</sup> Further research is necessary to establish the cost-effectiveness of approaches that have been recommended to date.<sup>84</sup>

## SUMMARY

Exposure and sensitization to indoor allergens play a critical role in allergic rhinitis. The principal allergens are derived from house dust mites, pets, cockroaches and other insects, and fungi. A complex interplay of genetics, allergen, and other environmental exposures is present. Interventions that have been successful in reducing allergen exposure are multifaceted and may be relatively expensive. Nonetheless, reducing allergen exposure to negligible levels has been shown to improve clinical outcomes. Studies that allow better insights into the complex interplay between the environment and genetics are necessary. Strategies to prevent allergic sensitization in at-risk populations are under ongoing investigation to provide improved allergen avoidance recommendations. Any avoidance measure should be targeted at the specific sensitivity demonstrated by the patient.

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