



Efficacy of environmental controls for inhalant allergies

James W. Mims and Ashley C. Biddy

Purpose of review

This review examines the efficacy of environmental controls as part of the management for inhalant allergic disease (allergic rhinitis and allergic asthma).

Recent findings

Evidence of efficacy of environmental controls for allergic disease can be categorized into two types of studies: environmental controls reducing measured allergen levels and environmental controls affecting clinical outcomes (e.g., symptom scores, medication use, or measured lung function). Multiple environmental control strategies have demonstrated efficacy in reducing allergen levels; however, clinical benefit secondary to allergen reduction has been variable. Clinical benefit is seen more consistently in studies that remove the allergic patient from a high allergen environment, than in studies that attempt to reduce the allergen level within the home. Prevention of sensitization using environmental controls in the prenatal and infant periods has been studied, but it has been difficult to demonstrate a consistent reduction in the development of allergic disease or decrease symptom severity. Allergen exposure early in life may paradoxically promote tolerance in some populations and sensitizations in others.

Summary

Although many studies evaluating a single environmental control strategy fail to show an improvement in clinical outcomes, comprehensive environmental controls may provide some benefit. Additionally, studies that relocate patients to low allergen environments tend to demonstrate clinical improvement.

Keywords

allergen avoidance, environmental control, house dust mite, pet allergens

INTRODUCTION

Inhalant allergic disease is prevalent and increasing. In the United States, allergic rhinitis affects 30–60 million people and asthma affects 18.7 million people [1[■],2]. Over the past 10 years, there has been a steady increase in newly diagnosed cases of inhalant allergic disease [3,4].

The development of allergic disease is likely predicated on genetic predisposition and exposure. However, the gene–environment interactions that underlie inhalant allergy are not fully understood at this time. A strong family history of allergic disease increases the likelihood that a child born of an atopic parent will become sensitized and develop allergies [1[■]]. Genetic studies of allergic disease have revealed hundreds of gene mutations regulating the phenotype of allergic inflammation [5]. However, twin studies have not shown full concordance in the development of allergic disease, even in identical twins raised in the same home [6]. Epigenetic influences on the manifestation of allergic disease exist, but are not well understood. Inhalant allergy is

currently viewed as a genetically heterogeneous propensity toward IgE-mediated inflammation that is influenced by epigenetic factors and environmental exposures.

The management of allergic disease falls into three general categories: immunotherapy, pharmacotherapy, and avoidance measures. Avoidance measures, also known as environmental controls, aim to decrease the allergen exposure in order to improve clinical symptoms or prevent sensitization. Most clinicians recommend avoidance measures in combination with other allergy therapies. Although the relationship between allergy symptoms and

Department of Otolaryngology, Head and Neck Surgery, Wake Forest School of Medicine, Winston Salem, North Carolina, USA

Correspondence to James W. Mims, MD, Department of Otolaryngology, Head and Neck Surgery, Wake Forest School of Medicine, Medical Center Blvd, Winston Salem, NC 27157, USA. Tel: +1 336 716 8964; fax: +1 336 716 9440; e-mail: wmims@wakehealth.edu

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KEY POINTS

- Multiple methods, including mattress and pillow covers, frequent linen washing, acaricides, dehumidifiers, high efficiency particulate air filters, and frequent vacuuming, are effective in reducing allergen levels.
- Clinical improvement secondary to allergen reduction has been variable, with multiple interventions showing greater benefit than single interventions.
- Movement to an alternate location, away from the source of the primary allergy stimulus, is effective in improving clinical symptoms of allergic disease.
- Primary prevention of sensitization in the prenatal and infant periods has not been shown to prohibit the development of allergic disease or decrease symptom severity.
- Pet exposure early in life may provide a protective effect on development of allergic sensitization and of allergic disease.

exposure is clearly seen in seasonal pollen allergy, persistent allergies, typically attributed to dust mites, mold, cockroach, and dander, have been the primary focus of research.

The scientific study of allergic environmental control dates to the 1980s when the first primary mite intervention study was performed [7¹¹]. Historically, allergen avoidance was heralded as the key to symptom management; however, more recent research has shown inconsistent efficacy [7¹²]. A 2010 Cochrane review suggested that ‘significant data were not present to suggest avoidance measures for house dust mite (HDM) allergy as a primary or even significant therapy’ [8]. Nonetheless, environmental controls are still widely considered part of the management of allergic rhinitis and allergic asthma.

This article reviews the evidence for environmental control strategies. Environmental control studies can be separated into three categories by outcome: allergen quantity, clinical measures (symptoms, medication use, change in pulmonary function) and prevention of sensitization. Studies assessing clinical outcomes can be further subdivided into those evaluating the effect of transferring an allergic patient to a different environmental setting and those studies that apply an environmental control into the home.

Perennial and seasonal allergens

Basic knowledge of the main classes of inhalant allergens is helpful in evaluating environmental control studies and counseling allergic individuals.

Outdoor allergen control involves recognizing peak allergen conditions and how to prevent bringing outdoor allergens into the home [9]. Pollen is relatively large in size, ranging from 15 to 50 μm , making it more likely to deposit in the nose than in the lower airways. Tree pollination occurs with three consecutive days of temperatures above 65°F with pollen levels being highest from 5 to 10 a.m. Hot, dry, windy days usually elicit the most symptoms as most allergic pollens are transported by wind rather than insects. Knowledge of local pollen seasons can be useful in counseling patients. Generally, tree pollen is prevalent in the spring, grass in the summer, and weed in the late summer and fall.

Mold spores are ubiquitous in our environment and are found indoors and outdoors [9]. Spores range in size from 5 to 50 μm and can survive boiling and freezing. Mold thrives in damp, shady areas with decaying vegetation. Mold can be a perennial or seasonal allergen, with elevated levels seen in early spring with the winter thaw, in summer with heavier rains, and in fall with decaying leaves. Given that low mold spore counts are 6500 spores/ m^3 [10] and that an average person inhales 18 m^3 daily [11], mold-spore exposure is difficult to avoid.

Environmental controls focus on indoor allergies given that we spend 90% of our lives indoors [9]. High indoor allergen levels are common. A cross-sectional study in the United States reported that 46% of homes had high levels of three or more allergens [12]. HDMs are the most common indoor allergens, and HDM sensitization serves as a predictor of asthma development. Two species of HDM, *Dermatophagoides pteronyssinus* (Dp) and *D. farinae* (Df), are the most common in North America and are carried on particles between 10 and 25 μm . These particles remain airborne for only a short period before settling [13¹⁴]. HDMs prefer climates with humidity above 50% and temperatures ranging between 65 and 84°F [9]. They feed off human skin and hair that collect predominantly on sheets, mattresses, and pillows.

Cockroaches tend to thrive around food and water sources. Cockroach sensitization is a major risk factor for childhood asthma and allergy. The inhaled allergen is not thought to originate from the living roach. The desiccated particles from dead roaches become airborne and spread through ventilation systems. Although it may seem that allergen levels would be highest in kitchens and bathrooms, high levels of allergen are found in bed sheets and mattresses, presumably tracked in on the feet, and provide a significant source for allergic sensitization [14].

Pets live in 60% of American households [9]. Cat dander is relatively small, roughly 5 μm , which

allows travel into the lower airways. The major cat allergen is Fel d 1. Dog dander is generally less allergenic than cat dander. Dander particles adhere to furniture and carpets due to its sticky nature. Levels of dog, cat, and even mouse allergen can exceed the thresholds for symptoms in school and work environments in which pets do not reside [3].

Nonallergic irritants may cause more symptoms in allergic patients due to existing inflammation. Irritants include tobacco smoke, perfume, and other chemicals. Irritants also play a role in the development of allergy. Exposure to maternal tobacco during pregnancy and infancy has been associated with asthma development and allergic sensitization [9]. Chemical irritants are present in the home, outdoors, and workplace. Frequent use of cleaning agents and exposure to products of combustion are common sources of irritant exposure, which can trigger symptoms. Frequent bleach use was positively associated with more frequent lower respiratory symptoms in asthma patients [13^{*}]. Further, air pollutants are often unavoidable in an industrialized country. The list of potential triggers and allergy sensitizers is long and constantly evolving. Consideration of irritants in the home and work environment, specifically exposure to tobacco smoke, should be included when counseling for inhalant allergies.

Environmental controls and reduction of allergen levels

Minimizing outdoor activities, closing windows, placing doormats, sealing entryways, removing shoes, removing indoor plants, and using 3% tannic acid spray to denature allergen have been recommended to reduce pollen (Table 1).

Studies using reduction of measured allergen as the outcome have primarily focused on cat dander and dust mite, two of the most significant indoor allergens. Studies measure allergen levels using multiple methods, including air filters, vacuums, or microscopic dust mite counts before and after an intervention. While reduction of allergen is necessary for an environmental control to be effective, it is important to recognize that allergen reduction could be achieved with no clinical benefit.

HDM reduction has been the focus of multiple studies given that it is the most common indoor allergen and a predictor of asthma and rhinitis development. Strategies that attempt to reduce or isolate reservoirs of HDM allergens include mattress and pillow covers, removing carpet, high efficiency particulate air (HEPA) filters, and vacuuming [1^{***}]. Mattress and pillow covers have been shown to reduce dust mite counts [15], at least temporarily.

Table 1. Effectiveness and pricing of control measures for outdoor allergens

Control measure	Effectiveness	Price
Closing windows	+++	\$
Removing shoes indoors	+++	\$
Tannic acid spray	+++	\$
Remove indoor plants	+++	\$

— Shown not to be effective, + recommended in literature, ++ reduces allergen levels, +++ improves clinical outcomes; \$ inexpensive, \$\$ moderately expensive, \$\$\$ expensive.

If utilizing covers, the remaining bedding must then be cleaned regularly. However, HDMs are able to survive a normal cycle through the washing machine and dryer. Some suggest unusually hot washing temperatures (130°F). However, this is above the temperature recommended by American Academy of Pediatrics and is associated with household burns [16]. HDMs can be killed by freezing, so placing bedding and stuffed animals overnight in the freezer has been recommended, but not studied. Removing carpet reservoirs may be useful and is frequently recommended. The efficacy of carpet removal is difficult to assess in a blinded study but it is recognized that solid floors store fewer particles than carpet. Vacuuming mattresses has been controversial [17] and did not seem to have much effect when HDM counts calculated through vacuuming (3–46 mites/m²) were compared from mattress biopsies under an electron microscope (8000–26 000 mites/m²) [18,19]. Counterintuitively, feather bedding has been shown to have fewer mites than synthetic bedding [20]. It has been suspected that mold associated with the feathers may compete with the mite population. Possibly, feathers have evolved to repel mites via unknown mechanisms.

Dust mites do not drink and require humidified air for water. Although dry climates and high altitudes do not support HDM populations, reducing HDM populations by reducing the humidity has met varied success. The critical humidity for dust mites is 73% at 25°C. However, Arlian *et al.* [21] showed that lowering humidity may not be efficient as it took 10 weeks for a dust mite population to die at 40–50% humidity in the laboratory. Also, temporary spikes in humidity (rainy days) may provide all the water dust mites require. It may be that dehumidifiers work better in moderate humidity than high humidity regions.

Mites are of the order Acari and acaricides are commercially available to kill mites. Acaricides have been effective in reducing live HDM counts

Table 2. Effectiveness and price for control measures for cockroach

Control measure	Effectiveness	Price
Baiting, cleaning	++	\$

– Shown not to be effective, + recommended in literature, ++ reduces allergen levels, +++ improves clinical outcomes; \$ inexpensive, \$\$ moderately expensive, \$\$\$ expensive.

but are less effective in reducing measured HDM allergen [22] (Table 2).

Pet allergens also contribute to allergen load in allergic disease. Pet removal from the home has been recommended; however, studies have not suggested that pet removal improves symptoms or prevents sensitization [23]. Bleach use has been found to reduce overall allergen sensitization in homes with pets [1²²]. Air filters may be beneficial and are discussed later. Cat washing does not appear to have a significant effect on home allergen levels [24] (Table 3).

Household insect allergens have also been studied. Pest management methods including the use of pesticides and baits, crack sealing, hole repair, and food source removal have been shown to decrease cockroach allergen levels [23] (Table 4).

Studies employing the combination of multiple interventions, such as mattress and pillow encasings, weekly bedsheet washing, twice weekly bedroom and living room vacuuming, removal of pets, and washing toys have also been shown to reduce total allergen load [22].

AIR FILTRATION

Air filtration systems are widely advertised but their addition to the home can be quite expensive. A 2010

Table 3. Effectiveness and price for control measures of house dust mites

Control measure	Effectiveness	Price
Bed covers	++	\$\$
HEPA filters	+++	\$\$\$
Vacuuming mattress	–	\$
Removing carpet	+	\$
Acaricides	+++	\$\$
Clean environment (high altitude, hospital)	+++	\$\$
Low humidity	++	\$
Bleach cleaning	++	\$

– Shown not to be effective, + recommended in literature, ++ reduces allergen levels, +++ improves clinical outcomes; \$ inexpensive, \$\$ moderately expensive, \$\$\$ expensive. HEPA, high efficiency particulate air.

Table 4. Effectiveness and price for control measures for pet dander

Control measure	Effectiveness	Price
Cat washing	–	\$
HEPA filters	+++	\$\$\$
Removing pets	–	\$

– Shown not to be effective, + recommended in literature, ++ reduces allergen levels, +++ improves clinical outcomes; \$ inexpensive, \$\$ moderately expensive, \$\$\$ expensive. HEPA, high efficiency particulate air.

comprehensive review of air filtration systems divided interventions into two categories: portable air cleaners and those installed on central heating and air-conditioning (HVAC) systems [25]. It was found that high efficiency filters on HVAC units were effective in reducing larger diameter particles, like cat and HDM allergens, but less effective for removal of smaller irritants, like tobacco smoke and pollutants [26]. HEPA filters, especially those that filter the breathing zone during sleep, were effective in reducing allergen levels and improving rhinitis symptoms. A double-blind, randomized controlled trial attached HEPA filters to pillow encasings and found improvement in nasal obstruction symptoms and quality-of-life measures in perennial allergic rhinoconjunctivitis sufferers [27]. HEPA filters are effective in reducing pet allergens, as well as allergy symptoms [26]. The overall recommendation of the review was for high-efficiency whole house filtration and a portable HEPA filter in the bedroom.

ENVIRONMENTAL CONTROLS AND CLINICAL OUTCOMES

Unfortunately, findings of clinical improvement after allergen reduction have not been as consistent. The 2012 Cochrane review for allergic rhinitis investigated nine trials that compared HDM control measures, including bed covers, HEPA filters, and acaricides in patients with clinically proven allergic rhinitis. It was concluded that acaricides were the most promising with significant reductions in rhinitis symptoms, whereas impermeable bedding was unlikely to prove effective [28]. A 2008 Cochrane review of allergic asthma investigated 54 studies utilizing either single or multiple allergen reduction interventions. They found no overall significant differences in morning peak flows, number of patients improved, asthma symptom scores, or medication usage in asthma sufferers [29].

The difficulty with environmental control measures and clinical outcomes is exemplified in cockroach allergy. Symptom thresholds for cockroach allergens in sensitized patients occur in the

range of 2–8 U/g of dust. Baiting and cleaning decreased cockroach allergen from 69 to 32 U/g in one study, and to 20 U/g in another [30]. These reductions were not adequate to reach the 2–8 U/g of dust symptom threshold and clinical effectiveness was not observed.

There are several reasons that environmental controls may not be clinically effective. Patients may be polysensitized and may be exposed to more than one environment, such as work or school. The re-suspension of settled dust with aggressive cleaning may negate any clinical improvement seen with allergen reduction [13[¶]].

TRANSFERRING ALLERGY SUFFERERS TO LOW ALLERGEN ENVIRONMENTS

The concept of moving patients to a different environment to control allergic symptoms dates back to the early Platts-Mills study. Patients placed in hospital rooms for at least 2 months were found to have symptom improvement and decreased medication use [31]. This clinical improvement has been replicated in more recent studies looking at occupational rhinitis. A large longitudinal study found that 45% of greenhouse workers had bell pepper allergy. Those that left work during the course of the study reported significant improvement in quality-of-life measures as well as reduction of rhinitis symptoms [32].

Moving to high altitudes has been studied. High altitudes are characterized by low humidity, clean air with reduced HDM and mold allergens [33]. High altitudes are a naturally HDM-free environment and serve as a natural escape from one of the biggest contributors to allergic asthma. Further, the pollen season is shorter and conifers outnumber more allergenic deciduous trees at high altitude. Improvement in clinical symptoms, decreased medication use, decreased airway hyperresponsiveness, and decreased serum IgE levels have all been documented in various studies with movement to high altitudes in asthma sufferers [33]. A recent prospective cohort study showed that asthma patients with allergic sensitization reported improved quality of life, decreased serum IgE and eosinophils, and decreased exhaled nitric oxide after spending 12 weeks at 1600 m altitude [34]. With return to the home environments, these improvements were reversed and approached baseline levels, suggesting that the high altitude environment was the cause of the improvement.

Low humidity hinders the growth of molds and other microbes [1^{¶¶}]. Higher indoor humidity was found to contribute to cough, wheeze, phlegm production, and increased airway hyperresponsiveness

[35]. Some authors have recommended reducing indoor humidity levels below 60% (Table 3).

ENVIRONMENTAL CONTROLS AND PREVENTING SENSITIZATION

Instituting environmental controls has been explored as a means to prevent allergen sensitization. Most studies have applied environmental controls in the homes of high-risk infants to prohibit allergic rhinitis and asthma.

Family history and IgE from umbilical cord blood have been used to select unborn children as at 'high risk' to develop allergic disease. Studies conflict as to whether umbilical cord blood IgE levels are predictive of subsequent inhalant allergies. Elevated levels of cord blood IgE have been found in infants of mothers with increased home exposure to cockroach and mouse during pregnancy [23]. A recent study found a synergistic effect of maternal stress and prenatal HDM allergen exposure in increasing cord blood IgE and showed a greater increase in cord IgE in those mothers with history of atopy. In theory, prenatal maternal exposure to allergens can reach fetal circulation, cause sensitization, and increase risk of allergic disease, especially those with a family history of atopy [36]. Early life exposure to allergens may increase risk in some children. Exposure to *Aspergillus*, *Alternaria*, and *Aureobasidium* molds by 3 months of age has been found to contribute to allergic rhinitis within the first 5 years of life [13[¶]] and has been positively associated with asthma and allergic disease development [37]. This premise was challenged by a 2010 study that found that cord blood mononuclear proliferation was not associated with later allergen sensitization or asthma at 5 years of age [38]. Also, several international studies found that homes cleaned with bleach weekly had decreased allergen exposure and atopic sensitization to indoor allergens in children [39,40].

Several large, well designed studies have been performed that randomize the introduction of environmental controls early in life to prevent allergic disease. Rao and Phipatanakul [23] found that implementing prevention measures before birth may decrease asthma risk later in life. Studies based in Canada [41], Isle of Wight [42], Manchester [43], and Europe [44] also showed some protective benefit. However, other large, well designed studies did not show such findings. A randomized double-blind study, the Prevention and Incidence of Asthma and Mite allergy study (PIAMA), instituted interventions prenatally with the use of mite-impermeable mattress and pillow covers on maternal beds and followed children longitudinally to assess

effectiveness of HDM reduction and development of sensitization and allergic symptoms. The investigators found only a temporary reduction in symptoms at age 2 and no long-term improvement in asthma symptoms [15]. Other birth cohort studies aimed at preventing asthma and/or allergic sensitization have also exhibited minimal results, including the larger Study of Prevention of Allergy in Children in Europe (SPACE) [45–47].

Early allergen exposure has also been found to have a potentially protective role. Infants born into homes with cats and dogs have been observed to have a lower rate of developing allergy [15,48–51]. However, the protective effect of having a household pet prenatally may vary between those of high and low allergy risk. For example, one study evaluated early pet exposure in relation to asthma and wheezing in children with mothers with and without asthma. They found that among children whose mothers had no history of asthma, exposure to a cat or a Fel d 1 concentration of at least 8 µg/g at the age of 2–3 months was associated with a reduced risk of wheezing between the ages of 1 and 5 years. However, among children whose mothers did have a history of asthma, such exposures were associated with an increased risk of wheezing at or after the age of 3 years. There was no association between wheezing and exposure to dog or dog allergen [52]. As the response to early exposure remains unclear, the current guidelines from the Global Initiative for Asthma is that there is 'currently insufficient evidence to provide any recommendations in relation to pet-keeping in early life and the development of asthma and allergic disease' [49,53].

Prevention studies have focused on whether reducing allergen exposure decreases the development of allergic disease. Conflicting results suggest that allergen exposure early in life may affect the development of immune tolerance as well as allergic sensitization. Further complicating our understanding, other factors that may influence the development of allergic disease may include microbial exposure, diet, breast feedings, vitamin D levels, and irritant exposures [7**].

CONCLUSION

Despite environmental controls that effectively reduce the level of measured allergens, the clinical benefits of these environmental controls range from modest to unproven. The degree of allergen reduction required for a clinical effect is more consistently achieved when patients are transferred to hospitals or high altitudes than when modifying the home environment. However, relocation is rarely practical. Studies that utilize multiple stringent

controls show promise but require a significant investment of resources. Additionally, instituting environmental controls in the pre or postnatal periods has not consistently shown to prevent the development of allergic disease. Allergen reduction may paradoxically promote sensitization in low-risk populations. Better understanding of how the immune system develops tolerance or hyperreactivity to common allergens is needed. When counseling on the utility of environmental controls, physicians should consider whether clinical benefits have been demonstrated. Nonetheless, unique opportunities exist in which altering the environment is likely beneficial, such as removing pet guinea pigs or eliminating second hand smoke exposure. A thoughtful individualized approach is warranted, and environmental controls should be advised in the context of available pharmacologic interventions and immunotherapy.

Acknowledgements

None.

Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 294–295).

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