

# Eradication of house dust mite from homes of atopic asthmatic subjects: A double-blind trial

Tin Htut, MB, MSc,<sup>a</sup> Tim W. Higenbottam, BSc, MA, MD, FRCP,<sup>a</sup> Gordon W. Gill, BSc, MSc,<sup>b</sup> Sr Ruth Darwin,<sup>b</sup> Paul B. Anderson, MA, FRCP,<sup>b</sup> and Nasir Syed, MB, MRCP<sup>b</sup> Sheffield, United Kingdom

**Background:** House dust mite (HDM) allergens can accumulate to very high levels in homes. From the observed sensitivity of HDMs to heat and their allergens to steam, a novel treatment of furnishings has been developed.

**Objective:** We sought to determine whether combined steam and heat treatment of home furnishings reduced asthmatic patients' bronchial hyperreactivity (BHR) and lowered HDM antigen loads.

**Methods:** The homes of 30 asthmatic subjects aged 18 to 45 years were randomly allocated into 3 groups. In groups 1 and 2 mattresses and duvets were treated with hot air (110°C), followed by steam and then heat again. All their carpets were steam cleaned. Group 2 also had a special ventilation system installed above each patient's bedroom. The homes of subjects in group 3 were sham treated. Neither patient nor laboratory staff was aware of the types of treatment. Der p 1 and 2 levels in the household dust from the lounge, bedroom carpet, and beds were determined before and after treatment and then at 6 and 12 months. BHR, measured by using histamine PD<sub>20</sub> values, was recorded during the 4-week run-in period and at 3, 6, 9, 12 months after treatment.

**Results:** Active heat-steam treatment of homes caused a sustained reduction of Der p 1 ( $P = .003$ ) and Der p 2 ( $P = .001$ ) compared with no change in sham-treated group 3 homes. Patients whose homes were treated showed a 4-fold reduction in BHR at 9 months in group 1 and throughout the posttreatment period in group 2. No change was observed in the asthmatic subjects whose homes were not treated. These improvements were sustained for 12 months in the homes with bedroom ventilation units.

**Conclusions:** A single treatment of home furnishings reduced mite allergen load to below the risk level for sensitization and improved the asthmatic patients' BHR by 4-fold. (*J Allergy Clin Immunol* 2001;107:55-60.)

**Key words:** Allergic asthma, indoor allergens, house dust mites, Der p 1, Der p 2, histamine challenge, combined steam-heat cleaning, environmental control

## Abbreviations used

BHR: Bronchial hyperreactivity  
HDM: House dust mite

House dust mites (HDM) are one of the most common sources of indoor allergens and are a cause of symptoms in allergic asthma. Group 1 and 2 HDM allergens cause over 80% of IgE response in atopic subjects.<sup>1</sup> The group 1 allergen of *Dermatophagoides pteronyssinus* (Der p 1) is associated with mite feces and is heat labile, whereas the group 2 allergen (Der p 2) is a body protein of the mites that is more resistant to heat than Der p 1.<sup>1</sup> Both allergens accumulate in high levels in homes.

Prevention of asthma should be possible by limitation of exposure to allergens. Clinical benefit from mite avoidance is seen when patients allergic to mites reside at high altitude,<sup>2,3</sup> but the symptoms recurred when they returned home. A low-allergen environment in the homes would be a better way of avoiding HDM exposure; however, such an environment has proved difficult to create with existing methods. Mites can be killed by freezing with liquid nitrogen,<sup>4</sup> and Der p 1 can be reduced substantially in carpets with steam cleaning.<sup>5</sup> A study using liquid nitrogen to treat the patient's bedroom, however, did not reduce HDM allergen levels in homes,<sup>6</sup> and steam cleaning may not be suitable to treat mattresses because it can leave residual moisture on the substrate.<sup>5,7</sup> A combination of acaricide and tannic acid has also been used to treat furnishings in many studies,<sup>8-11</sup> but it was not effective in creating a low-allergen environment, or the effect was of a short duration. The popular method to contain and isolate the allergen by encasing bedding with a barrier material also gives variable results.<sup>10-16</sup>

A new method of treatment of mattresses and bedding with heat followed by steam eradicates HDM and reduces dust Der p 1 levels.<sup>17</sup> We report a field study of the efficacy of this method in a range of asthmatic subjects' city homes. Addition of home ventilation was tested for its capacity to prevent reinfestation of the treated environment.

## METHODS

### Patients

From October 1996 to August 1997, asthmatic subjects aged 18 to 45 years were recruited by advertisements in a newspaper, GP surgeries, and the Chest Clinic. Ethics committee approval and

From <sup>a</sup>Respiratory Medicine, Division of Clinical Sciences (CSUHT), Medical School, University of Sheffield, Sheffield; and <sup>b</sup>Chest Clinic, Northern General Hospital (NGHT), Sheffield.

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Reprint requests: Tim W. Higenbottam, BSc, MA, MD, FRCP, Director of Division of Clinical Sciences (CSUHT), Medical School, University of Sheffield, Beech Hill Rd, Sheffield S10 2RX, United Kingdom.

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patients' informed consent were obtained. Skin prick testing with HDM, cat, dog, grass, and tree pollen antigens (Soluprick, ALK) was undertaken. Those patients with a wheal of 3 mm or greater in diameter to HDM antigen, together with a 15% rise in FEV<sub>1</sub> after inhaled (200 µg) salbutamol, were included. Those with cats at home who were allergic to cats were excluded, as were those who had planned to move in the next 12 months.

### Study design

The study was randomized and double blind, and 30 adult asthmatic subjects were allocated into 3 groups of equal size. Recruitment was sequential, and randomization into 3 groups was done by drawing numbers. The homes of group 1 subjects received the heat-steam-heat treatment, and those of group 2 subjects also had a special ventilation system installed in the loft above each patient's bedroom. Group 3 subjects had a sham treatment of their homes.

All patients had lung function measured, including a bronchial histamine challenge test. Patients and their homes were studied over 12 months, with a run-in period of 4 weeks.

### Mite eradication and home ventilation

Trained technicians (Mediclean) performed the mite eradication. The surfaces of the carpets and upholstery of the homes of groups 1 and 2 were steam cleaned. For mattresses, dry heat, defined as air heated to greater than 110°C, was delivered with a metal probe inserted at a single point of the mattress at the head end. Duvets were treated together with the mattresses by using them as a cover for the mattress to conserve heat. Heating was continued until the surface temperature of the mattress reached 80°C. Steam was then applied for 2 minutes, followed by hot air to dry the fabric. Patients were given a new set of pillows, and bed linen was washed using a 60°C cycle. Group 3 homes were sham treated with the same equipment but without heat and steam.

A positive ventilation system (Nuair) was installed in the loft above the group 2 patients' bedrooms. It supplied fresh warm and filtered air into the bedroom at one air exchange rate per hour, together with background ventilation of the homes.

### Quantification of mite exposure

Dust was collected by vacuuming a 1-m<sup>2</sup> area of carpets and the whole upper surface of the uncovered mattresses. Der p 1 was quantified from the dust by using ELISA (ALK; <12% intra-assay coefficient of variation). Der p 2 was quantified by using ELISA (Indoor Biotechnologies). Dust samples were collected from the lounge carpet, the subject's mattress, and from a third site, which was either a bedroom carpet or a mattress that had the highest initial mite level.

The Der p 1 level of the dust collected from the 3 sites in each home was determined before and after treatment and then at 6 months and 12 months. The Der p 2 level of the dust collected from the patients' beds was determined at similar time intervals as for Der p 1.

### Severity of asthma

Bronchial responsiveness to inhaled histamine (histamine PD<sub>20</sub>) was determined during the 4-week run-in period and at each clinic visit at baseline and 3, 6, 9, and 12 months.

### Analysis of the results

A team without knowledge of the treatment groups collected the results of the lung tests. A scientist who was unaware of the study design also undertook allergen quantification of the dust samples.

The analysis was made with the statistical software package SPSS. All the data were transformed to the natural log after assigning the data with zeroes to a constant of 0.01. Missing values were also calculated.

We used factorial ANOVA, with either 2- or 3-way interactions, depending on the experimental design. The 95% confidence intervals for comparisons of the sequential means after the treatment were calculated by using the residual variance.<sup>18</sup>

## RESULTS

### Der p 1 and Der p 2 levels

There were no differences among the mean baseline levels of Der p 1 of the 3 treatment groups ( $P = .7$ ), but the allergen levels changed between groups with time ( $P = .03$ ). Within the homes, levels of antigen were higher in the mattresses than in the carpets, and the levels changed significantly with time.

The geometric mean Der p 1 level of 3 sites (lounge carpet, patient's bed, another bed or carpet) in group 1 fell from  $7.4 \pm 1.3$  µg/g (mean  $\pm$  SE) to  $1.1 \pm 1.4$  µg/g after treatment,  $1.9 \pm 1.3$  µg/g at 6 months, and  $3.3 \pm 1.6$  µg/g at 12 months. In group 2 it fell from  $6.5 \pm 1.4$  µg/g to  $1.3 \pm 1.4$  µg/g after treatment and was  $2.2 \pm 1.8$  µg/g at 12 months when the bedroom was ventilated. There was no significant change in Der p 1 from the baseline of  $2.7 \pm 1.5$  µg/g in group 3.

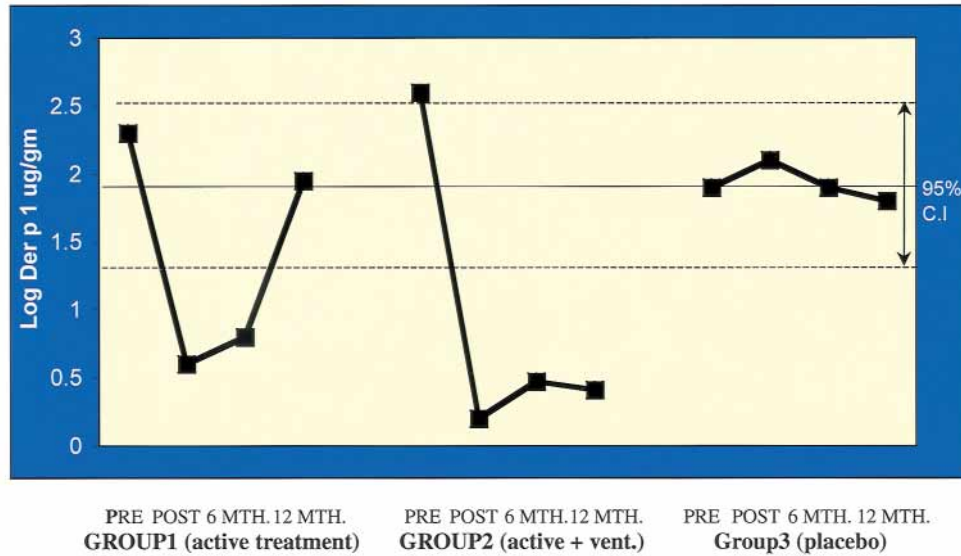
The logarithm-transformed Der p 1 levels of each patient's bed (Fig 1) showed significant differences with time ( $P = .01$ ). In group 1 the mean allergen levels of the patients' beds fell by 6-fold from the baseline of  $10.4 \pm 1.6$  µg/g. The levels remained low for 6 months but went back to 1.5-fold of the baseline at 12 months. In group 2, where the bedroom was ventilated, the allergen levels were reduced by 11-fold from the baseline of  $14 \pm 1.7$  µg/g and remained below  $1.6 \pm 1.7$  µg/g throughout the study period (Fig 1). In group 3 there were no significant changes from the baseline level of  $6.7 \pm 1.7$  µg/g throughout the study period.

In the lounge carpet geometric mean Der p 1 level of group 1 before treatment was  $3.2 \pm 1.7$  µg/g. It was  $0.9 \pm 1.6$  µg/g after treatment,  $1.3 \pm 1.5$  µg/g at 6 months, and  $3 \pm 1.9$  µg/g at 12 months. In group 2 it was  $2.3 \pm 1.6$  µg/g before treatment,  $1.2 \pm 2$  µg/g after treatment,  $4.2 \pm 1.8$  µg/g at 6 months, and  $4.4 \pm 2$  µg/g at 12 months. In group 3 it was  $0.9 \pm 1.6$  µg/g at baseline,  $1.2 \pm 1.7$  µg/g after treatment,  $2.2 \pm 2.2$  µg/g at 6 months, and  $2.7 \pm 1.6$  µg/g at 12 months.

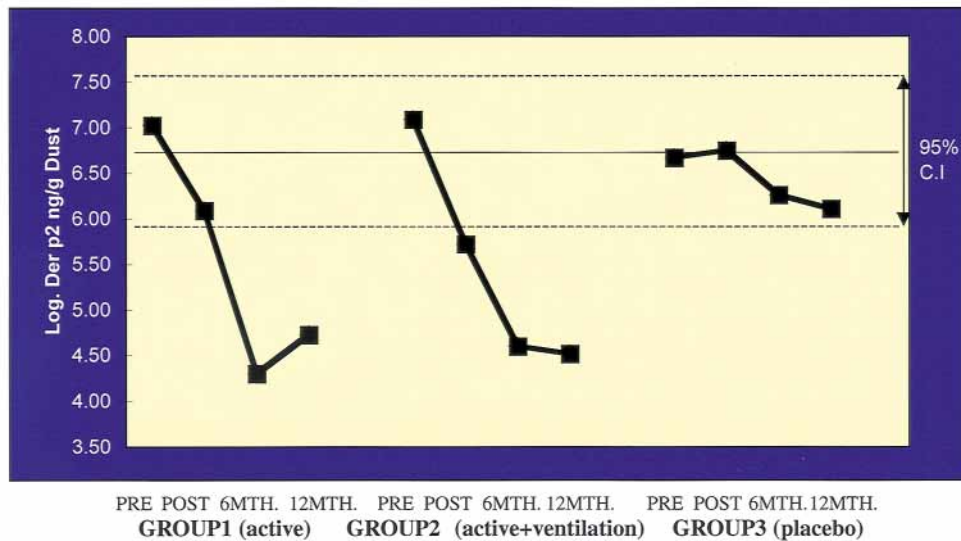
There were also significant differences in Der p 2 levels of mattresses with time ( $P = .001$ , Fig 2). In the active groups Der p 2 concentrations fell progressively after the mite eradication but not with the sham group.

### Severity of asthma

The logarithm-transformed histamine PD<sub>20</sub> levels of patients at 5 time points are shown in Fig 3. There was a significant change with time on ANOVA ( $P = .05$ ). The mean logarithm-transformed histamine PD<sub>20</sub> level rose in group 1 by 4-fold by 9 months. In group 2, where the bedroom was ventilated, improvements in bronchial hyperreactivity (BHR) were seen as early as 3 months after the treatment, and the 4-fold improvement was sustained for 12 months. There was only a small change ( $\leq 2$ -fold) in PD<sub>20</sub> values at 6 months in the sham-treated group 3 homes (Fig 3).



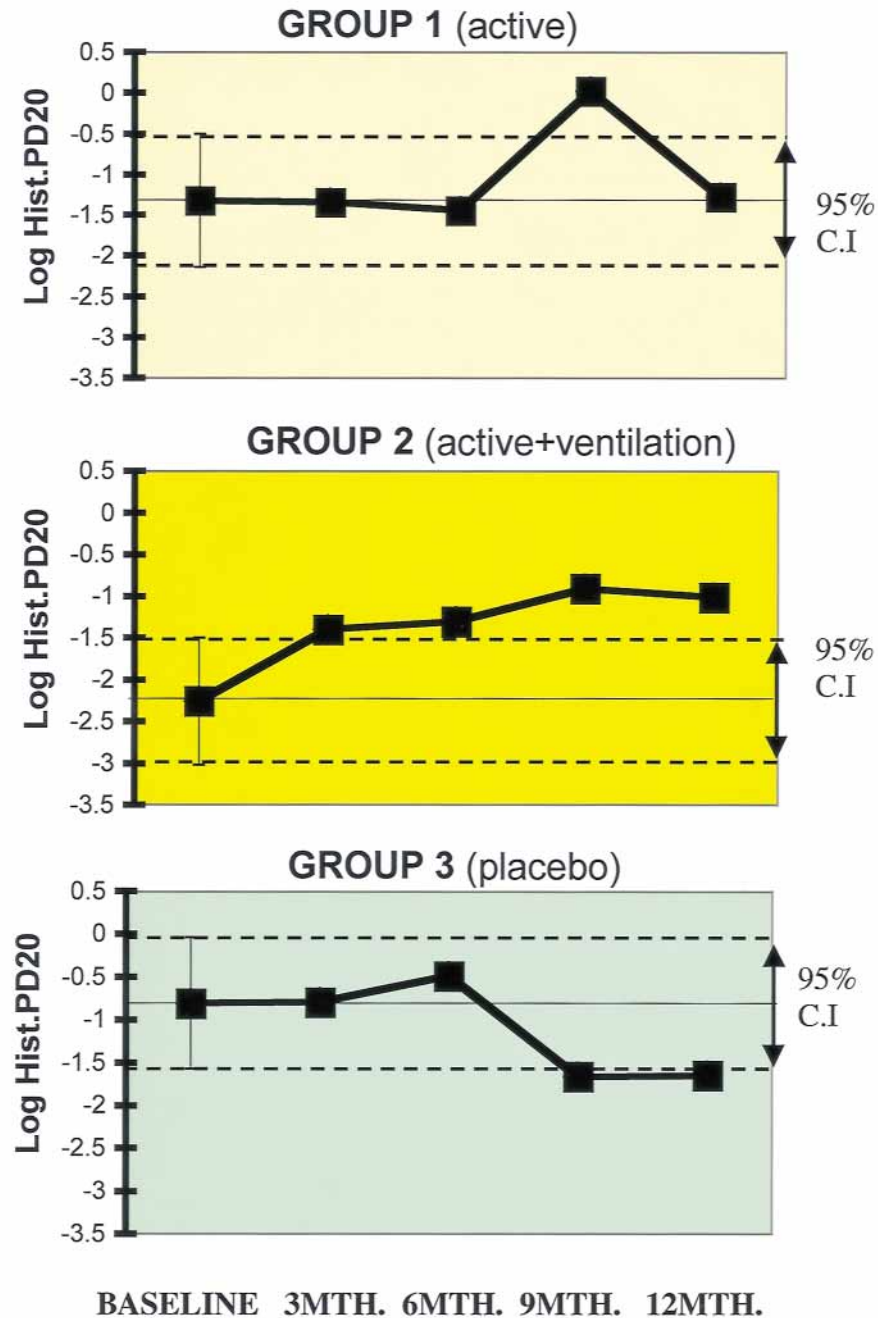
**FIG 1.** The logarithm-transformed mean Der p 1 level in micrograms per gram of mattress dust and 95% confidence interval constructed from the residual variance to compare the placebo group with the active groups. Group 1 had active mite eradication, group 2 had a positive ventilation system in the subject's bedroom in addition to mite eradication, and group 3 had a sham cleaning. Der p 1 is an enzyme associated with mite feces, and it tends to accumulate with time. The posttreatment Der p 1 concentrations of the actively treated groups, but not the sham-treated group, fell below the baseline level. The allergen levels remained low for 6 months in group 1 and for 12 months in group 2, where the bedroom was positively ventilated. There is a significant difference between groups with time ( $P = .03$ ) with ANOVA.



**FIG 2.** The logarithm-transformed mean and Der p 2 in nanograms per gram of mattress dust and 95% confidence interval constructed from the residual variance to compare the placebo group with the active groups. Der p 2 is a body protein, and the levels may represent the mite population. The posttreatment Der p 2 concentrations of the actively treated groups, but not the sham-treated group, fell below the baseline and remained low for 12 months. There is a significant difference between groups with time ( $P = .001$ ) with ANOVA.

Seven patients in total did not finish the study because of personal problems. Four subjects left the study at 6 months as they moved homes. Three more did not come for the last round of histamine challenge. Full clinical data were obtained from 23 subjects: group 1,  $n = 7$ ; group 2,  $n = 8$ ; and group 3,

$n = 8$ . Allergen data were obtained from all 30 homes before and after treatment but from 26 homes at 12 months because we managed to collect dust samples from the homes of 3 subjects who did not turn up for histamine challenge. Three hundred two dust samples were analyzed, and 58 samples were



**FIG 3.** The mean and 95% confidence intervals constructed from the residual variance of logarithm-transformed histamine PD<sub>20</sub> values in millimoles per milliliter of the 3 groups are shown. There was a significant difference within groups with time ( $P = .05$ ) with ANOVA. In group 1, with active treatment, histamine PD<sub>20</sub> rose at 9 months but returned to baseline by 12 months. In group 2, with active treatment plus ventilation, the histamine PD<sub>20</sub> level rose progressively over 12 months. By comparison, the histamine PD<sub>20</sub> level fell in the untreated group.

missing. One hundred nineteen histamine challenges were performed, and 31 values were missing.

## DISCUSSION

The Der p 1 and Der p 2 levels fell after a single heat-steam-heat treatment of the homes in contrast to sham

treatment of homes. The value of the steam-heat method is emphasized by the significant fall in Der p 2 that is more heat stable than that in Der p 1. What is more, the levels remained lowered for longer, perhaps reflecting the value of Der p 2 to estimate mite numbers. The reduction in mite body proteins reflects mite numbers rather than antigen accumulation with time. The asthmatic

patients in the homes of the active groups experienced a 4-fold reduction in bronchial hyperresponsiveness, unlike those patients in sham-treated homes in whom the responsiveness increased. Addition of ventilation systems above the patients' bedrooms sustained improvements in BHR and allergen level for 12 months.

This treatment of home furnishings was simple. Steam cleaning to the surfaces of carpets and then a sequence of heating and steam was delivered to the center of the mattresses through an inserted probe. It took an average of 4 hours to treat a 3-bedroom house. The cost was £500 (\$800). The special loft ventilation installed above the patients' bedrooms added a further £400 (\$640) to the cost.

Alternative approaches where a number of measures, including barriers on the mattresses and replacement of mattresses and carpets, together with cleaning report equivalent reduction in mite allergen.<sup>16</sup> These are more expensive (~£800 [\$1200]) and leave the mattresses infested with mites.

The effectiveness of our treatment of furnishings depends on the sequential combination of dry heat followed with steam. The heat kills the mites,<sup>17</sup> whereas steam denatures the tertiary structure of the antigen and limits its ability to initiate the hypersensitivity response.<sup>19</sup> The unique feature of this method is the insertion of a probe into the mattresses that delivers heat-steam to the center, where the mites nest.

Surface treatment of mattresses with agents such as liquid nitrogen and chemicals are not effective on their own but need additional measures,<sup>4-12</sup> whereas surface treatment with steam was successful to the carpets, as has been reported with other treatments.<sup>5,7</sup> Treatment of the surface alone fails to penetrate through the layers of the mattress.

The failure of earlier methods to reduce the allergen load or to produce consistent changes in asthma<sup>8-15</sup> could be explained by their inability to decrease levels of mite or allergen in mattresses and partly for not treating the whole house. Frequent applications of multiple methods of eradication, with repeated cleaning or chemical treatment, can be effective over a period of time,<sup>10,20-22</sup> but they are expensive in terms of time and money, and chemicals can be potentially toxic. The heat-steam technique does not damage fabrics, and the sequence of heat first and then steam followed by heat again leaves the mattress completely dry.

Additional ventilation seemed to be effective in preventing reinfestation when the allergen load was very low after the intervention. However, improvement of ventilation alone may not be effective in the United Kingdom because of milder winters and high allergen load in homes.<sup>23,24</sup> Improvements in ventilation may be effective if the allergen load is first reduced. We suspect that annual testing of the home for evidence of reinfestation would be of value in determining whether a further treatment of furnishings is needed. Mattress barrier covering might also prevent reinfestation once full eradication has been undertaken, but this needs to be tested.

To evaluate the effect of mite avoidance on the severity of asthma, we used the histamine test of BHR. Unlike other measurements, such as peak flow diary cards, which are poor measures of asthma severity,<sup>25,26</sup> and quality-of-life questionnaires, which need a large sample size,<sup>27</sup> BHR offers an objective laboratory-based measure of severity of asthma,<sup>28-30</sup> and it is a sensitive indicator for small-size studies.

A single heat-steam treatment of home furnishings reduced mite allergen levels. This caused a significant improvement in BHR of asthmatic subjects. These improvements were sustained when a unit was installed to ventilate the patient's bedroom after the home had been heat-steam treated.

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## REFERENCES

1. Platts-Mills TAE, Vervloet D, Thomas WR, Aalberse RC, Chapman MD. Indoor allergens and asthma: report of the Third International Workshop. *J Allergy Clin Immunol* 1997;100:S1-24.
2. Custovic A, Simpson A, Chapman MD, Woodcock A. Allergen avoidance in the treatment of asthma and atopic disorders. *Thorax* 1998;53:63-72.
3. Colloff MJ, Ayres J, Carswell F, Howarth PH, Merrett TG, et al. The control of allergens of dust mites and domestic pets: a position paper. *Clin Exp Allergy* 1992;22(Suppl 2):1-28.
4. Dorward AJ, Colloff MJ, MacKay NS, McSharry C, Thomson NC. Effect of house dust mite avoidance measures on adult atopic asthma. *Thorax* 1988;43:98-102.
5. Colloff MJ, Taylor C, Merrett TG. The use of domestic steam cleaning for the control of house dust mites. *Clin Exp Allergy* 1995;25:1061-6.
6. Kalra S, Crank P, Hepworth J, Pickering CAC, Woodcock AA. Concentrations of the domestic house dust mite allergen Der p1 after treatment with solidified benzyl benzoate (Acarosan) or liquid nitrogen. *Thorax* 1993;48:10-3.
7. Siebers R, Rains N, Crane J, Fitzharris P. Effect of superheated steam cleaning of carpets on house-dust-mite allergen Der p 1 [abstract 80]. Proceedings of the Lancet Conference on the Challenge of Asthma; 1997; Tours, France. *Lancet* 1997;(Suppl):350.
8. Dietemann A, Ressort JC, Hoyet C, Ott M, Verot A, Pauli G. A double-blind, placebo controlled trial of solidified benzyl benzoate applied in dwellings of asthmatic patients sensitive to mites: clinical efficacy and effect on mite allergens. *J Allergy Clin Immunol* 1993;91:738-46.
9. Warner JA, Marchant JL, Warner JO. Allergen avoidance in the homes of atopic asthmatic children: the effect of Allersearch DMS. *Clin Exp Allergy* 1993;23:279-86.
10. Marks GB, Tovey FR, Green W, Shearer M, Salome CM, Woolcock AJ. House dust mite allergen avoidance: a randomised controlled trial of surface chemical treatment and encasement of bedding. *Clin Exp Allergy* 1994;24:1078-83.
11. van der Heide S, Kauffman HF, Dubois AEJ, deMonchy JGR. Allergen avoidance measures in homes of house dust mite allergic asthmatic patients: effects of acaricides and mattress encasing. *Allergy* 1997;53:921-7.
12. Walshaw MJ, Evans CC. Allergen avoidance in house dust mite sensitive adult asthma. *Q J Med* 1986;58:199-215.
13. Nishioka K, Yasueda H, Saito H. Preventive effect of bedding encasement with microfibre fibres on mite sensitisation. *J Allergy Clin Immunol* 1998;101:28-32.
14. Frederick JM, Warner JO, Jessop WJ, Enander I, Warner JA. Effect of a bed covering system in children with asthma and house dust mite hypersensitivity. *Eur Respir J* 1997;10:361-6.
15. Jooma OF, Weinberg EG, Berman D, Manjara AI, Potter PC. Accumulation of house dust mite (Der p 1) levels on mattress covers. *S Afr Med J* 1995;85:1002-5.

16. Custovic A, Simpson BM, Simpson A, Hallam C, Craven M, Brutsche M, et al. Manchester Asthma and Allergy Study: low-allergen environment can be achieved and maintained during pregnancy and early life. *J Allergy Clin Immunol* 2000;105:252-8.
17. Htut T, Houlbrook K, Lumley E, Maunder JW, Vickers L. A novel physical method to control mites and their allergens in bedding. *Int J Environ Health Res* 1996;6:233-43.
18. Gardner S, Winter P, Gardner M. CIA: confidence interval analysis. London, UK: BMJ Publishing; 1991.
19. Htut T, Gill G, Darwin R, Syed N, Ketchell I, Anderson PB, et al. Inactivation of Der p 1 demonstrated by skin-prick testing [abstract]. *Thorax* 1997;53(Suppl 6):P34.
20. Ehnert B, Lau-Schadendorf S, Weber A, Buettner P, Schou C, Wahn U. Reducing domestic exposure to dust mite allergens reduces bronchialhyperreactivity in sensitive children with asthma. *J Allergy Clin Immunol* 1992;90:135-8.
21. Weeks J, Oliver J, Birmingham K, Crewes A, Caswell F. A combined approach to reduce mite allergen in the bedroom. *Clin Exp Allergy* 1995;25:1179-83.
22. Carswell F, Birmingham K, Oliver J, Crewes A, Weeks J. The respiratory effects of reduction of mite allergen in the bedrooms of asthmatic children; a double blind controlled trial. *Clin Exp Allergy* 1996;6:386-96.
23. McLNiven R, Fletcher AM, Pickering AC, Custovic A, Sivour JB, Preece AR, et al. Attempt to control mite allergens with mechanical ventilation and dehumidification in British houses. *J Allergy Clin Immunol* 1999;103:756-62.
24. Fletcher A, Pickering CAC, Custovic A, Simpson J, Kennaugh J, Woodcock A. Reduction in humidity as a method of controlling mites and mite allergens: the use of mechanical ventilation in British domestic dwellings. *Clin Exp Allergy* 1996;26:1051-6.
25. Nunn AJ, Gregg I. New regression equations for predicting peak expiratory flow in adults. *BMJ* 1989;298:1068-70.
26. Gregg I, Nunn AJ. Peak expiratory flow in symptomless elderly smokers and ex-smokers. *BMJ* 1989;298:1071-2.
27. Hyland ME, Crocker GR. Validation of an asthma quality of life diary in a clinical trial. *Thorax* 1995;50:724-30.
28. Barnes N. Evaluating asthma and its treatment: clinical markers and indicators of efficacy. *Eur Respir Rev* 1996;6:31-7.
29. Rodriguez-Roisin R. Physiological markers of airway inflammation in asthma. *Eur Respir Rev* 1996;6:19-22.
30. Cockcroft DW, Ruffin RE, Dolovich J, Hargreaves PE. Allergen-induced increased in non-allergic bronchial reactivity. *Clin Allergy* 1977;7:235-43.