Partial mattress encasing significantly reduces house dust mite antigen on bed sheet surface: a controlled trial

Orathai Jirapongsananuruk, MD*; Nat Malainual, MSc†; Pasuree Sangsupawanich, MD*; Vithune Aungathiputt, MD*; and Pakit Vichyanond, MD*

Background: The most effective measure in house dust mite antigen reduction is mattress encasing with an impermeable membrane. A reduction in encasing costs will help increase patients' compliance in mite antigen avoidance.

Objective: To investigate the effectiveness of partial mattress encasing with a nylon sheet produced in Thailand on the reduction of group I mite antigens from beddings.

Methods: Sixty regularly-used beds from the house officers' dormitory of the Siriraj Hospital Mahidol University, Thailand, were randomly matched into two groups according to mite antigen levels. The control group (CG) used only regular cotton bed sheets whereas the partial encasing group (PG) used mattresses partially covered with a locally produced nylon sheet underneath the regular cotton bed sheets. Dust collection from the beddings was performed at baseline, 2, 4 and 6 months after application of the nylon sheet. Mite antigen levels were detected by a two step monoclonal antibody ELISA.

Results: Mite antigen levels in both groups were not different at the beginning of the study. The PG had significantly lower group I antigen levels on regular bed sheet surfaces than the CG ($P < .004$) at the 2, 4 and 6 month timepoints. However, antigen levels on the mattress surface of the PG was significantly higher than the CG at the end of the study ($P < .004$). The barrier efficacy of the nylon sheet in preventing migration of group I mite antigens from the mattress to the surface of the regular cotton bed sheet was 94% whereas that of the regular cotton bed sheet was 66% ($P = .007$).

Conclusion: Partial mattress encasing with a locally made nylon sheet can reduce mite antigens on the regular cotton bed sheet surfaces for up to 6 months.

Ann Allergy Asthma Immunol 2000;84:305–310.

INTRODUCTION

House dust mite is considered a major indoor antigen worldwide.[1] The role of house dust mite antigen in the provocation of atopic diseases such as asthma and atopic dermatitis has been well established.[2,3] In asthmatic patients, house dust mite antigen avoidance leads to an improvement of symptom scores and peak expiratory flow rates as well as a decrease in the degree of bronchial hyperesponsiveness.[4–7] In atopic dermatitis, house dust mite antigen avoidance also provides significantly greater improvement in severity score and area affected in avoidance group than in controls.[8]

Several measures have been reported to reduce house dust mites and their antigen with variable success. These measures include bed encasing with a mite-impermeable membrane, carpet removal, acaricides, denaturants, freezing and solar exposure.[9] Of all these methods, bed encasing has been shown to be the most effective method for isolating afflicted individuals from the mites and their antigens in the bedding.[10] Currently, there are mattress cover products made from polyurethane coated fabric or a complete impermeable membrane available worldwide. These products are recommended for complete mattress encasing.

Most mattresses in Thailand are situated on a hard wooden bed frame instead of on box springs. The mattresses are commonly covered by a special nylon sheet in a fitted sheet manner that has anecdotally been found to be clinically effective in reducing the mite antigens which induce allergic symptoms. This method of mattress encasing which we will call partial mattress encasing, together with the utilization of a locally produced nylon material, can significantly decrease the cost of mite antigen avoidance and, therefore, increase compliance among patients, especially those of low socioeconomic status.

The objective of our study is to determine the effectiveness of a locally produced nylon sheet covering mattresses in a fitted sheet manner, in the reduction of mite antigen available to patients on bedding surfaces.

MATERIAL AND METHODS

Subjects

Sixty mattresses from the house officers' dormitory at the Siriraj Hospital, Mahidol University, Bangkok, Thailand, were divided into 2 groups according to group I mite antigen levels. The difference of antigen levels in each matched pair did not exceed 20%. In the control group (CG), mattresses

* Division of Allergy and Immunology, Department of Pediatrics and † Department of Parasitology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.

Supported by the Siriraj China Medical Board Fund #75-348-254, Mahidol University, Bangkok, Thailand.

Received for publication March 17, 1999.

Accepted for publication in revised form October 30, 1999.

were covered with only the regular cotton bed sheets, whereas in the partial encasing group (PG), the tops and sides of the mattresses were partially covered with the special nylon sheets prior to placement of the regular cotton bed sheets. Pillows were covered with the same nylon sheets in the regular manner. These special nylon sheets were locally produced in Thailand with a tight weaving pattern which can prevent dispersion of fine particles when disturbed. The mattresses were 5 years old on average and were situated on wooden frames ($90 \times 195 \times 8$ cm^3). They were used 5 days per week. There was no air conditioning but ventilation was well maintained via 3 windows and 2 doors per room. The floor of the room was cement without carpets or rugs. Bed sheets were washed every 2 weeks. The temperature and humidity closest to the mattresses were recorded at the time of dust collection. Dust samples were collected from each pair (CG and PG) at the same time. Dust collections were scheduled to cover all seasons in Thailand.

Dust Samples

Dust were collected at baseline and at 2, 4, and 6 months after mattress encasing. Dust samples were collected from the upper surfaces of the bed sheets from all mattresses. In addition, dust from the mattress surfaces was collected at baseline and at the 6-month timepoint to examine the changes in antigen levels within the mattresses. At the 6-month timepoint, samples from the inner surfaces of the bed sheets in the CG and both the upper and inner surfaces of the nylon sheets in the PG were also collected.

Each dust sample was collected by vacuuming a 1 m^2 area for 2 minutes with a vacuum cleaner (Kelvinator 1000 W) attached to a dust collector (ALK laboratory, Denmark). Different areas of the sheet were utilized when collecting samples from the upper and lower surface of the same sheet. Collected samples were sealed in plastic bags and stored frozen to kill all live mites. The samples were then sieved through a 1 mm mesh screen in order to obtain a fine dust and stored at 4°C until the time of analysis.

Two Step Monoclonal Antibody (mAb) ELISA for Group I Mite Antigen Measurement

A 2-step mAb ELISA was performed for detection of the group I mite antigen in the dust samples as described previously by Luczynska et al.[11] The specific mAb (5H8, 6A8, and 4C1) and the standard group I mite antigens (Der p I, Der f I) used in the assay were purchased from Indoor Biotechnology (Deeside, UK). Briefly, the mite antigens were extracted by mixing 0.1 g of fine dust in 2 mL PBS buffer for 2 hours at room temperature. For samples weighing less than 0.1 g, PBS was added to achieve a 1:20 dilution (wt/vol). After centrifugation, the supernatant was stored at −20°C for analysis. Samples were diluted with 1% BSA-PBS-Tween to 1:10, 1:20, 1:40 and 1:80 in order to detect a wide range of antigen levels. Mite antigen levels in the samples were determined by interpolating their absorbances on the standard curve and were corrected for dilution factor. Antigen levels were expressed as μg/g of fine dust.

Statistical Analysis

The data was natural log transformed prior to analysis to produce an approximately normal distribution. A series of repeated measure analysis of variance (ANOVA) models were performed. The paired matching on antigen level was incorporated in the analysis as a random effect. A compound symmetric variance structure was assumed. All pairwise comparisons between pairs of mean were made using the Tukey-Kramer multiple comparison procedure. The efficacy of nylon sheet and regular bed sheet was compared between the paired PG and CG using Wilcoxon Signed-Rank test. All findings were considered significant at P value of $\leq .05$.

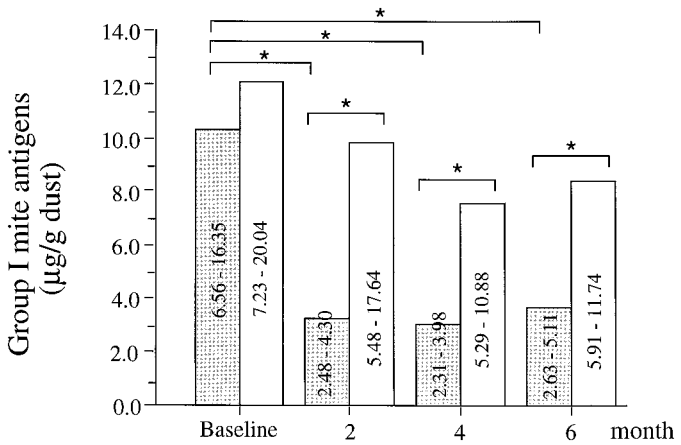

Figure 1. Group I mite antigen levels on regular cotton bed sheets in the partial encasing group (PG) are significantly lower than in the control group (CG). Group I mite antigen levels were determined for the regular cotton bed sheets of both groups at baseline, 2, 4, and 6 months. The gray bars represent the geometric mean values of mite antigen levels in the PG while the white bars represent the geometric mean values of mite antigen levels in the CG. The 95% confidential interval values are shown in the bars. (*$P < .05$).

RESULTS

Thirty bed pairs were matched by group I mite antigen levels both on the regular bed sheets and the mattresses at the beginning of the study as shown in Figures 1 and 2. Throughout the study, the ambient temperature ranged from 28.8°C to 32.5°C with a mean of 30.6°C. The relative humidity ranged from 40.7% to 69.5% with a mean of 55.6%. Der f I was found to comprise over 89% of the group I antigens detected in both groups (data not shown).

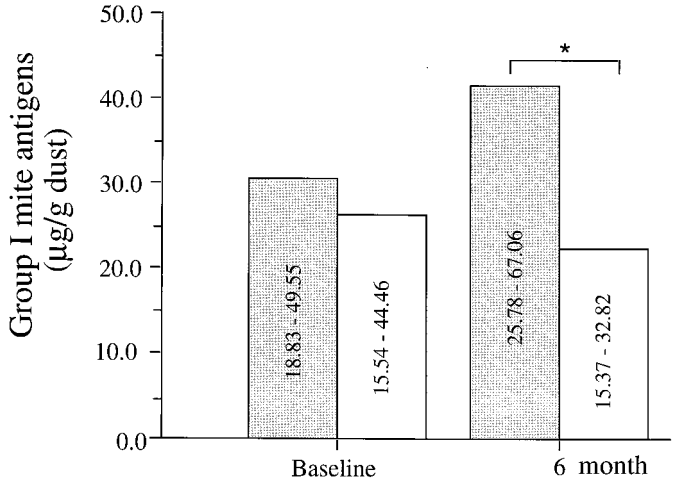

Figure 2. Group I mite antigen levels on mattresses in the partial encasing group (PG) are significantly higher than in the control group (CG). Group I mite antigen levels were determined for the mattresses of both groups at baseline and 6 months. The gray bars represent the geometric mean values of mite antigen levels in the PG while the white bars represent the geometric mean values of mite antigen levels in the CG. The 95% confidential interval values are shown in the bars. (*$P < .05$).

Mite Antigen Levels on Regular Cotton Bed Sheets

Mite antigen levels on regular cotton bed sheets were measured in both groups at baseline, 2, 4, and 6 months of the study. As shown in Figure 1, group I mite antigens in the PG were significantly lower than in the CG after the application of nylon sheet at the 2-, 4-, and 6-month timepoints. The group I antigens in the PG, at the 2-, 4-, and 6-month timepoints were significantly decreased from baseline ($P < .001$) whereas no significant change was observed in the CG ($P > .05$). The antigen reduction effect was more prominent for Der f I because it was the major house dust mite antigen found in this study (data not shown).

Mite Antigen Levels on Mattresses

Mite antigen levels on the mattresses were measured at the beginning and at the completion month of the study for both groups. In Figure 2, group I antigens in the PG were significantly higher than in the CG at the end of the study ($P = .007$).

Mite Antigen Levels at Different Bedding Sites at the End of the Study

Group I mite antigens at different bedding sites were measured and compared within each group at the end of the study. In Figure 3, group I antigens in the PG on the top of the nylon sheets was significantly lower than the antigen levels found on the mattress surface ($P < .0001$) and under the nylon sheets ($P < .002$). Conversely, group I antigen levels found on top of the regular bed sheets were not significantly different from the antigen levels on top of the nylon sheet ($P > .05$).

In Figure 4, group I antigen levels on the mattress surface in the CG at the end of the study were higher than on top of and under the regular bed sheet ($P < .003$). Antigen levels under and on top of regular bed sheets were not significantly different from one another.

Barrier Efficacy of Nylon Sheets Versus Regular Cotton Bed Sheets

The barrier efficacy of the nylon membrane versus the regular bed sheets for each pair was determined by dividing the difference of the group I antigen levels on the mattress and on the regular bed sheet by the group I antigen levels on the mattress. The median barrier efficacy of the nylon membrane for preventing migration of group I antigens from mattress to the bed sheet surface was 94% whereas that of regular cotton bed sheet was 66%. The Wilcoxon Sign-Rank test performed to compare efficacies between the groups demonstrated a significantly higher barrier efficacy for the nylon sheet

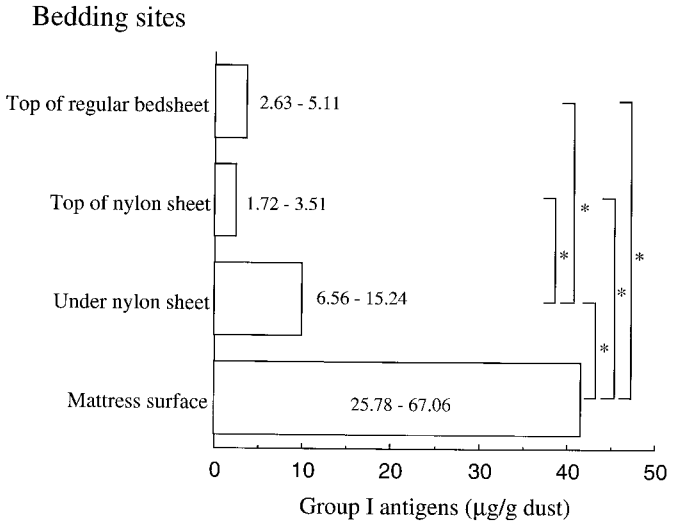

Figure 3. Group I mite antigen levels at different bedding sites in the partial encasing group (PG) at the 6-month timepoint. Dust collected from the different sites of bedding in the PG was analyzed for group I mite antigen levels at the 6-month timepoint. The bars represent the geometric mean values of group I mite antigen levels. The 95% confidential interval values are shown in the bars. (*$P < .05$).

over the regular cotton bed sheet (P = .001).

DISCUSSION

House dust mite is the most common aeroallergen causing asthma and allergic rhinitis in Thailand. Eighty-four percent of adult asthmatics[12] and 67% of childhood asthmatic[13] are sensitized to house dust mite as determined by skin testing. Furthermore, 88% of allergic rhinitis children are skin prick test positive to house dust mite.[14] *Dermatophagoides pteronyssinus* (Dp) and *D. farinae* (Df) are the most common house dust mite species found in the average Thai home.[15] Sensitization to house dust mite is common among Thai patients due to the warm and humid climate throughout the year which favors growth of house dust mites. According to a previous study, the major habitats for house dust mites in Thai houses are pillows and mattresses.[15] Box springs and carpets which are other major sources of antigen are rarely used in the average Thai homes; therefore, efforts for mite antigen reduction consists primarily of mattress and pillow encasement. Partial mattress encasing in a fitted sheet manner has been a common practice since most mattresses are laid directly on solid surfaces such as floors or hard wood frames. This practice reduces the cost of encasing materials. For example, the cost of partially encasing a king sized mattress in the local made nylon sheet costs US $25 while complete encasing in the imported nylon sheet costs more than US $65. The decreased expense of partial mattress encasing could therefore increase compliance, especially among patients of low socioeconomic status, as demonstrated previously.[16]

Baseline mite antigen levels in the CG and the PG from this study (12.04 and 10.35 μg/g dust) correspond with the mean group I antigen level on the beddings observed in our previous study in Thailand (11.8 μg/g dust).[15] We demonstrated that a local made nylon sheet in the PG applied in a partially encasing manner, significantly reduced mite antigen levels on regular cotton bed sheet surfaces below those found in the CG throughout the 6-month study. This effect was seen more prominently with Der f I, the major antigen encountered in this study. Although Der p I antigen in the PG was less than in the CG at the 2-, 4-, and 6-month timepoints, we could demonstrate a statistically significant difference between the PG and the CG only at the 2-month timepoint. This may be due to the low level of Der p I antigen at baseline. The group I antigens on the regular bed sheet in the PG was significantly reduced after the nylon sheet was applied and remained significantly lower than baseline throughout the study. Our finding was similar to a study by Owen et al[1,7] demonstrating the effect of an impermeable membrane in reducing mattress mite allergens (with cover in situ) at the 6th and 12th week of the study. Although complete mattress encasing is generally recommended, Sarsfield et al[18] using partial encasing similar to our study, reported a reduction of mite counts as well as an improvement of asthma symptoms.

The increase of mite antigen levels on the mattress in the PG at the end of the study is consistent with results of a study by Tovey et al who demonstrated increased levels of mattress mite antigen of 150% of baseline beneath the encasing.[19] This phenomenon may be explained if the nylon membrane used in our study acted as a barrier that decreased ventilation and increased humidity within the mattresses thereby providing optimal conditions for house dust mite growth.

To investigate directly the barrier effect of the nylon sheet versus the regular cotton sheet at the end of the study, group I mite antigen levels at different bedding sites were measured and barrier efficacy of the membrane was calculated. In the PG, the barrier efficacy of the nylon sheet was 94%. Mite antigen levels on top of the regular bed sheet was similar to that on top of the nylon sheet indicating that the regular bed sheet did not provide any additional barrier for this group. In the CG, the barrier efficacy of regular bed sheet was only 66%.

The finding that Df is the predominant species of house dust mite in this study was different from our previous findings which demonstrated that Dp was the major species found in most Thai houses.[15] We hypothesize that

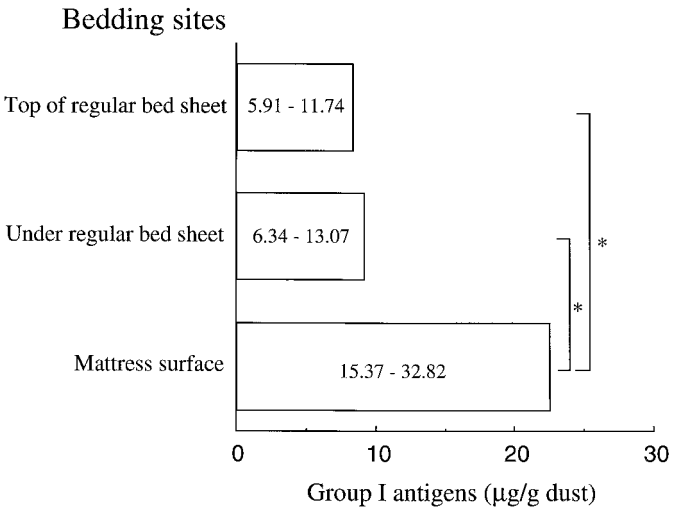

Figure 4. Group I mite antigen levels at different bedding sites in the control group (CG) at the 6-month timepoint. Dust collected from the different sites of bedding in the CG was analyzed for group I mite antigen levels at the 6-month timepoint. The bars represent the geometric mean values of group I mite antigen levels. The 95% confidential interval values are shown in the bars (*P < .05).

since Df survives longer than Dp in the low humidity of laboratory settings,[20] the relatively low humidity in the dormitory (55.6%) compared to average Thai homes (70%) may explain the predominance of Df in this study.

Although our study did not address the clinical significance of house dust mite reduction by mattress encasing, several studies have demonstrated the correlation between house dust mite exposure and the development and severity of atopic diseases. Kuehr et al demonstrated that sensitization to mite antigen was significantly associated with the new onset of asthma along with a history of parental atopy.[2] In asthmatic patients, Der p I and Der p II antigen levels in the beds correlated significantly with bronchial hyperresponsiveness and peak expiratory flow variability but correlated negatively with percent predicted FEV_1.[21] In atopic dermatitis, disease severity was associated with an increased concentration of mite on mattresses.[22] A number of studies have demonstrated effects of mite antigen reduction by mattress encasing in patients with atopic diseases. Bedding encasing resulted in a decrease in symptoms, medication used, low peak flow rate-days, and an improvement of bronchial hyperesponsiveness in mite-sensitive asthmatic children.[18,23] In atopic dermatitis patients who were sensitive to mites, mite avoidance by encasing, benzyltannate spray, and a high filtration vacuum cleaner resulted in a significant greater improvement in severity scores and area affected in a double-blind controlled trial.[8] These studies support the major role of mattress encasing as a house dust mite avoidance measure in atopic diseases.

In summary, our finding indicates that in situations where mattresses are located on solid surfaces, partial encasing is effective in mite antigen reduction. This could lead to a substantial decrease in the cost of mite antigen prevention and increased compliance in the low-income population. Whether such findings are applicable to mattresses which are located on boxsprings or in carpeted rooms needs to be investigated in the future.

ACKNOWLEDGEMENTS

We would like to thank David R. McCormick, MS, from National Jewish Medical and Research Center, Denver, CO, USA, for his great contribution in data analysis of this study. We would like to thank Amy P. Fehringer, BA, for her help in proof reading this manuscript. We are gratefully indebted to Dr. Martin D. Chapman of the University of Virginia, Charlottesville, Virginia, USA for his continuing support of our research on mite allergy.

REFERENCES

1. Platts-Mills TAE, de Weck AL. Dust mite allergens and asthma—a world wide problem. J Allergy Clin Immunol 1989;83:416–427.
2. Kuehr J, Frischer T, Meinert R, et al. Sensitization to mite allergens is a risk factor for early and late onset of asthma and for persistence of asthmatic sign in children. J Allergy Clin Immunol 1995;95:655–662.
3. Mitchell EB, Crow J, Chapman MD, et al. Basophils in allergen-induced patch test sites in atopic dermatitis. Lancet 1982;1:127–130.
4. Dorward AJ, Colloff MJ, Mackay NS, et al. Effect of house dust mite avoidance measures on adult atopic asthma. Thorax 1988;43:98–102.
5. Van der Heide S, Kauffman HF, Dubois AEJ, de Monchy JGR. Allergen avoidance measures in homes of house-dust mite allergic asthmatic patients: effects of acaricides and mattress encasings. Allergy 1997;52:921–927.
6. Hayden ML, Perzanowski M, Matheson L, et al. Dust mite allergen avoidance in the treatment of hospitalized children with asthma. Ann Allergy Asthma Immunol 1997;79:437–442.
7. Carswell F, Birmingham K, Oliver J, et al. The respiratory effects of reduction of mite allergen in the bedrooms of asthmatic children: a double blind controlled trial. Clin Exp Allergy 1996;26:386–396.
8. Tan BB, Weald D, Strickland I, Friedmann PS. Double blind controlled trial of effect of house dust mite allergen avoidance on atopic dermatitis. Lancet 1996;347:15–18.
9. Platts-Mills TAE, Vervloet D, Thomas WR, et al. Indoor allergen and asthma: report of the Third International Workshop. J Allergy Clin Immunol 1997;100:S1–24.
10. Colloff MJ, Ayres J, Carswell F, et al. The control of allergens of dust mites and domestic pets: a position paper. Clin Exp Allergy 1992;22(Supp 2):1–28.
11. Luczynska CM, Arruda LK, Platts-Mills TAE, et al. A two-site monoclonal antibody ELISA for the quantification of the major Dermatophagoides spp. allergens, Der p I and Der f I. J Immunol Meth 1989;118:227–235.
12. Wongsathauythong S. House dust mites and allergic bronchial asthma. J Med Assoc Thailand 1971;54:411–413.
13. Tuchinda M, Habanananda S, Vareenil J, et al. Asthma in Thai children: a study of 2000 cases. Ann Allergy 1987;59:207–211.
14. Jirapongsananuruk O, Vichyanond P. Nasal cytology in the diagnosis of allergic rhinitis in children. Ann Allergy Asthma Immunol 1998;80:165–170.
15. Malainual N, Vichyanond P, Phan-Urai P. House dust mite fauna in Thailand. Clin Exp Allergy 1995;25:554–560.
16. Denson-Lino JM, Willies-Jacobo LJ, Rosas A, et al. Effect of economic status on the use of house dust mite avoidance measures in asthmatic children. Ann Allergy Asthma Immunol 1993;71:130–132.
17. Owen S, Morgamstern M, Hepworth J, Woodcock A. Control of house dust mite antigen in bedding. Lancet 1990;335:396–397.
18. Sarsfield JK, Gowland G, Toy R, Norman ALE. Mite-sensitive asthma of childhood, trial of avoidance measures. Arch Dis Child 1974;49:716–721.
19. Tovey E, Marks G, Shearer M, Woolcock A. Allergens and occlusive bedding covers. Lancet 1993;342:126.
20. Arlian LG, Confer PD, Rapp CM, et al. Population dynamics of the house dust mites Dermatophagoides farinae, D. pteronyssinus, and Euroglyphus maynei (Acari: Pyroglyphidae) at specific relative humidities. J Med Entomol 1998;35:46–53.
21. Wickman M, Korsgaard J. Transient sensitization to house-dust mites: a

study on the influence of mite exposure and sex. Allergy 1996;51:511–513.
22. Beck H-I, Korsgaard J. Atopic dermatitis and house dust mites. Br J Dermatol 1989;120:245–251.
23. Murray AB, Ferguson AC. Dust free bedrooms in the treatment of asthmatic children with house dust or house dust mite allergy: a controlled trial. Pediatrics 1983;71:418–422.

Requests for reprints should be addressed to:
Orathai Jirapongsananuruk, MD
National Jewish Medical & Research Center
Department of Pediatrics, Rm K735
1400 Jackson St
Denver, CO 80206.