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

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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.


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 hyperresponsiveness.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
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 × 195 × 8 cm³). 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 mattress at baseline and at the 6-month timepoint to examine the changes in antigen levels within the mattresses. Dust collections were scheduled to obtain a fine dust and 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 ≤ .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).
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 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 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.
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 \(\mu g/g\) dust) correspond with the mean group I antigen level on the beddings observed in our previous study in Thailand (11.8 \(\mu g/g\) 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\(^{17}\) 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...
since Df survives longer than Dp in the low humidity of laboratory settings, 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. In asthmatic patients, Der p I and Der p II antigen levels in the blood correlated significantly with bronchial hyperresponsiveness and peak expiratory flow variability but correlated negatively with percent predicted FEV1. In atopic dermatitis, disease severity was associated with an increased concentration of mite on mattresses. 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 hyperresponsiveness in mite-sensitive asthmatic children. In atopic dermatitis patients who were sensitive to mites, mite avoidance by encasing, 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 hyperresponsiveness in mite-sensitive asthmatic children.

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.

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