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ENVIRONMENTAL DETERMINANTS

Daily Vacuuming of Mattresses Significantly Reduces House Dust Mite Allergens, Bacterial Endotoxin, and Fungal β-Glucan

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Background and aims. Atopic patients are advised to cover their mattresses with occlusive coverings; however, these are not cheap. We investigated whether daily vacuum cleaning of mattresses significantly reduces content of house dust mite allergens, bacterial endotoxin, and fungal β-glucan. *Methods*. Twenty volunteers vacuumed their mattress daily for 8 weeks. Dust samples collected at two weekly intervals were analyzed for house dust mite allergens (Der p 1 and Der f 1) by double monoclonal antibody ELISA and for endotoxin and β-glucan by the *Limulus* amoebocyte lysate kinetic assay. Results are presented as geometric means with 95% confidence interval (CI). *Results*. Total house dust mite allergens (Der p 1 + Der f 1) significantly reduced from a geometric mean (95% CI) of 4.07 μg (2.44–6.79) at the start to 0.42 μg (0.21–0.81) at week 8. Total endotoxin and β-glucan were also significantly reduced from 13.6 EU (8.6–21.4) to 3.4 EU (2.3–5.0) and from 94.4 μg (57.1–156.2) to 19.7 μg (10.2–37.9), respectively (p for trend >.0001). Percentage reductions in total house dust mite allergens, endotoxin, and β-glucan after 8 weeks of daily vacuum cleaning were 85.1% (80.1–90.1), 71.0% (70.4–81.0), and 75.7% (70.4–81.0), respectively. This was mainly due to a 77.7% (70.8–84.7) reduction in total dust. *Conclusion*. Daily vacuum cleaning of mattresses over time significantly reduces house dust mite allergens, endotoxin, and β-glucan. This gives atopic patients a practical and cheaper alternative to reduce their exposure to indoor house dust mite allergens and microbial bio-contaminants.

Keywords endotoxin, house dust mite, mattress, vacuuming, β-glucan

INTRODUCTION

Nowadays, about 90% of our lives are spent indoors and exposure to indoor bio-contaminants plays a significant role in allergic diseases and asthma. Of interest over the years has been the role of indoor allergens from house dust mites and domestic animals and its significance to allergic diseases. Lately, indoor microbial products from bacteria and fungi have also been shown to have a significant role in allergic diseases. Studies have consistently shown that sensitization to house dust mite allergens is strongly associated with asthma in children and adults (1, 2), that the development of atopy and asthma follows early childhood exposure (3), that strict avoidance to house dust mite allergens reverses asthma symptoms (4, 5), and that there is a dose–response relation between house dust mite allergen exposure and the severity of asthma in house dust mite-sensitized children (6).

Epidemiological studies have suggested that microorganisms and their components, particularly bacterial endotoxin and fungal β-glucan, may play a role in the prevalence of asthma and may account for the frequently observed association between home dampness and prevalence and severity of respiratory symptoms (7). Microorganisms are suspected to play a role not only as producers of IgE-inducing allergens, but also as a source of various agents that may induce nonimmunogenic inflammatory reactions which may account for the occurrence of adverse respiratory effects (8, 9).

It is increasingly being recognized that the bedroom is the main source of exposure as we spend approximately one-third of our lives in bed with allergen and microbial bio-contaminants in bedding close to the airways. Indeed, it has been shown that asthma symptoms in house dust mite-sensitized asthmatics was positively related to levels of house dust mite allergens in mattresses, but not in bedroom floors (10). Allergic asthmatics are advised to practice allergen avoidance. The main advice is to cover mattresses, duvets, and pillows with allergen-impermeable covers. However, many patients do not do this, most likely due to the expense of totally covering all of the bedding (11).

Various studies have shown associations between frequency of vacuuming and lower allergen levels (12–14) and one study showed that daily vacuuming over a 6-week period reduced allergen levels in carpets by about 68% but returned to pre-study levels when daily vacuuming was stopped and weekly vacuuming resumed (15). To our knowledge, no such studies have been conducted on endotoxin or β-glucan levels. Furthermore, to our knowledge, there have been no studies that determined whether frequent vacuum cleaning of mattresses reduces allergen or microbial bio-contaminant levels although one study found that vacuuming the mattress more than twice a

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year resulted in significantly lower house dust mite allergen (16) while another study found that weekly vacuuming of mattresses had no effect on house dust mite allergens but did reduce cat and dog allergens (17). The aim of our study was to determine whether daily vacuum cleaning of mattresses significantly reduces house dust mite allergens, bacterial endotoxin, and fungal β-glucans over time.

Material and Methods

Participants

We asked 20 staff members of the Show Chwan Memorial Hospital to participate. In order to increase compliance with the daily vacuum cleaning each participant was given a new vacuum cleaner (Philips Model FC8202, 1100 Watts, Shanghai, China). This also ensures that the vacuuming was done with the same wattage vacuum cleaner as the suction strength is directly related to the amount of dust collected. This vacuum cleaner was only used by the participants for daily vacuuming of mattresses, not for any other vacuuming regimes and dust bags were not emptied during the testing period.

The study and objectives were explained to the participants who gave written informed consent. Ethical approval of the study was granted by the Show Chwan Memorial Hospital Ethics Committee. The participants were asked to vacuum the top of the whole bare mattress every day for 2 minutes over an 8-week period. They also recorded the dates they vacuumed and dates when they did not with reasons of why.

Dust Collection and Preparation

Before commencing the daily vacuum cleaning, a research nurse visited each participant's home and obtained a vacuumed dust sample from the mattress over a 1 M^2 area for 1 minute, as previously described (12). The research nurse then collected further mattress dust samples at 2-week intervals during the 8-week study period.

Dust samples from mattresses are generally fine dust and were not sieved. We have previously shown that not sieving does not affect house dust mite allergen levels (18). For house dust mite allergens, 100 mg aliquots of dust were extracted with 1 ml of phosphate-buffered saline at room temperature. For endotoxin, 200 mg aliquots of dust were extracted with 5.0 ml of pyrogen-free water containing 0.05% Tween-20. For β-glucan, 20 mg aliquots of dust were extracted with 20.0 ml of 0.3N NaOH. All extracts were stored at −4°C before analysis.

Allergen, Endotoxin, and β-Glucan Measurements

The house dust mite allergens, Der p 1 and Der f 1, were determined in the phosphate-buffered saline extracts by double monoclonal antibody ELISA methods using commercial kits from Indoor Biotechnologies (Charlottesville, VA, USA), as previously described (19).

The pyrogen-free water dust extracts were analyzed for endotoxin by a kinetic chromogenic amebocyte lysate method using a commercial kit (Bio-Whitaker, Walkersville, MD, USA) on 1:500 dilutions as previously described (19).

β-Glucan levels were determined in the NaOH extracts by a kinetic chromogenic amebocyte lysate method using a commercial kit (Cape Cod, Falmouth, MA, USA) on 1:1000 dilutions as previously described (19).

Data Analysis

We analyzed the data using the statistical package R, version 2.10.1 (Vienna, Austria, 2010). Results are reported as geometric means. We used the Wilcoxon sum-rank test to test for the differences between weeks. For the test for trend we used a linear mixed model (lme function in the R lme4 library). In order to allow for missed days of vacuuming the number of times vacuumed was used as the base of trend. This model uses two levels: in the first level (intra-house) each house sequence of log daily responses is modeled by an intercept term and a term for the number of times cleaned; on the next level (inter-house) the term for the number of times cleaned is evaluated for a linear trend. The *p*-values for this linear trend term are reported here. This model was used to account for the repeated measurements on the house. The model finds the estimate of effect size that maximizes the model likelihood. We tested the model's goodness-of-fit by examining the QQ plots for the fitted models. Statistical significance was set at the p .05 level. Due to imperfect compliance in daily vacuuming, as a sensitivity analysis we also looked at the trend in allergen levels with number of days of vacuuming carried out.

Results

Of the 20 participants, six vacuumed every day for the 8-week period (56 days). The other 14 participants missed vacuuming on some days (due to not being home on particular dates) ranging from 1 to 21 days. Missing days were accounted for in the statistical analysis as described above in the data analysis. Overall, daily vacuuming was done 91.4% of the time. The results reported here are for the intervention of asking people to vacuum daily; the trend of reduced allergen levels was the same when we looked at the actual number of times vacuuming was done (data not shown).

Expressed as concentrations per amount of dust, there were reduction in house dust mite allergens over the 8-week vacuuming period, but not for endotoxin or β-glucan (Table 1). The reduction in house dust mite allergens was significant for Der f 1, but just failed to reach statistical significance for Der p 1 (p for trend .06).

When expressed as total amounts, there was a significant reduction in house dust mite allergens, endotoxin, and β-glucan levels over the 8-week vacuuming period (Table 2). The amount of recoverable dust from the 1 M^2/1 minute dust sampling procedures also significantly reduced from a geometric mean level of 1.50 g at the start of the study to 0.27 g at the end of the 8-week vacuuming period. Table 3 shows that there was a significant

TABLE 1.—Geometric means (95% CI) of house dust mite allergens, endotoxin, and β-glucan as concentrations per amount of dust.

	Week 0	Week 2	Week 4	Week 6	Week 8	P-value for trend
Der p 1 (μg/g)	0.68 (0.32–1.40)	0.59 (0.28–1.23)	0.43 (0.16–1.14)	0.45 (0.19–1.10)	0.46 (0.23–0.92)	.086
Der f 1 (μg/g)	1.18 (0.60–2.30)	1.32 (0.86–2.04)	0.94 (0.63–1.40)	0.7 (0.38–1.30)	0.69 (0.41–1.14)	.001
HDM (μg/g)	2.72 (1.86–3.97)	2.25 (1.42–3.58)	1.80 (1.07–3.05)	1.75 (1.11–2.76)	1.47 (0.90–2.38)	<.0001
Endotoxin (EU/mg)	91 (64–130)	108 (75–155)	94 (71–123)	98 (76–125)	97 (75–125)	.468
β-Glucan (μg/g)	63.2 (46.1–86.6)	59.3 (44.4–79.3)	92.8 (65.2–132.0)	69.1 (50.5–94.5)	75.1 (54.1–104.0)	.091

Notes: CI, confidence interval.
HDM= Der p 1 + Der f 1.

TABLE 2.—Geometric means (95% CI) of house dust mite allergens, endotoxin, β-glucan, and dust weights as total amounts.

	Week 0	Week 2	Week 4	Week 6	Week 8	P-value for trend
Der p 1 total (μg)	1.00 (0.45–2.25)	0.35 (0.16–0.73)	0.24 (0.10–0.59)	0.21 (0.09–0.49)	0.14 (0.06–0.32)	<.0001
Der f 1 total (μg)	1.18 (0.60–2.30)	0.65 (0.32–1.32)	0.35 (0.18–0.68)	0.24 (0.11–0.49)	0.20 (0.11–0.38)	<.0001
HDM total (μg)	4.07 (2.44–6.79)	1.12 (0.55–2.25)	0.69 (0.33–1.43)	0.57 (0.28–1.16)	0.42 (0.21–0.81)	<.0001
Endotoxin total (EU)	136 (86–214)	68 (46–105)	60 (48–76)	38 (26–57)	34 (23–50)	<.0001
β-Glucan total (μg)	94.4 (57.1–156.2)	28.4 (14.7–55.0)	37.0 (19.2–71.4)	23.7 (11.9–47.1)	19.7 (10.2–37.9)	<0.0001
Dust weight (g)	1.50 (1.12–2.00)	0.49 (0.32–0.74)	0.36 (0.23–0.57)	0.31 (0.20–0.49)	0.27 (0.18–0.41)	<.0001

Notes: CI, confidence interval; EU, endotoxin units.
HDM= Der p 1 + Der f 1.

TABLE 3.—Percentage reduction in total amounts of house dust mite allergens, endotoxin, and β-glucan after 8 weeks of daily vacuum cleaning.

	Mean (95% CI)
Der p 1	81.8% (75.3–88.2)
Der f 1	86.3% (80.9–91.7)
HDM	85.1 % (80.1–90.1)
Endotoxin	71.0% (58.8–83.2)
β-Glucan	75.7% (70.4–81.0)
Dust weight	77.7% (70.8–84.7)

Notes: CI, confidence interval.
HDM= Der p 1 + Der f 1.

percentage reduction in all parameters at the end of 8 weeks of daily vacuum cleaning.

DISCUSSION

This study has shown that daily vacuuming of mattresses significantly reduces total amounts of house dust mite allergens, endotoxin, and β-glucan. This reduction in total amounts is most likely due to a reduction in dust from the mattress through daily vacuuming which does not necessarily eventuate in a reduction of their concentrations. However, the concentrations of Der f 1 and Der p 1, expressed per gram of dust, did decrease unlike endotoxin and β-glucan. A possible reason is that the daily vacuuming also decreased the number of live house dust mites over time and thus leads to a decreased production of allergens. However, we did not assess the effect of daily vacuum cleaning on house dust mite numbers.

To our knowledge, there has been only two other studies that looked at the effect of daily vacuum cleaning on house dust mite allergens. Adilah et al. (15) vacuumed carpeted floors daily (except for weekends) for a 6-week period and found that total amounts of Der p 1 decreased on average 68% over that period. We achieved greater percentage reductions in house dust mite allergens than in the New Zealand study but our study time was longer, 8 versus 6 weeks. From our study data we hypothesize that greater reduction could have been achieved if the study time had been extended beyond the 8-week period. As can be seen from the data in Table 2, the week eight total amounts of house dust mite allergens, endotoxin, and β-glucan were the lowest compared to the other weeks and there was a downward trend throughout the study period.

The New Zealand daily vacuuming study did find that total amounts of Der p 1 returned to pre-study levels 6 weeks after daily vacuuming was stopped and weekly vacuuming resumed. We did not assess that in our study but it would be likely that the same would happen in mattresses, given previous studies showing that new allergen-free mattresses and pillows rapidly accumulate house dust mite allergens over time (20, 21). This suggests that frequent vacuuming needs to be maintained to keep allergen and bio-contaminant levels low and this may lead to noncompliance if daily vacuuming has to be done long-term. It would be of interest to determine whether a less frequent vacuuming regime, such as twice a week, would also result in significant reductions over time.

Popplewell et al. conducted a study where house dust mite allergic patients were instructed to daily vacuum living room and bedroom carpets and at least weekly their mattress with either standard or high-efficiency vacuum cleaners (17). After 1 year there was no significant change in Der p 1 from carpets or mattresses while a significant reduction was found for the cat allergen, Fel d 1, in all sites. Dog allergen, Can f 1, was also reduced in the mattresses. Interestingly, despite no decrease in Der p 1, patients also sensitized to cat but not possessing a cat, showed significant improvement in lung function.

Various studies have demonstrated that more or less frequent vacuuming is associated with either lower or higher endotoxin and β-glucan levels (22–25). To our knowledge, our study is the first to show that daily vacuuming of mattresses significantly reduces endotoxin and β-glucan levels as well as house dust mite allergens.

It is generally recommended that atopic patients adopt allergen-avoidance practices. One major advice is that patients completely cover their mattresses and bedding with impermeable covers although one study demonstrated that as a single intervention this was not clinically effective in adult asthmatics (26). A meta-analysis also concluded that house dust mite control measures were ineffective (27). However, these studies have been criticized for their study design (28). Some other studies have shown them to be clinically effective when combined with other allergen-avoidance measures (29). However, compliance with multiple allergen-avoidance measures is generally poor (11).

Conclusion

Daily vacuuming of mattresses significantly decreased levels of house dust mite allergens, endotoxin, and β-glucan. This method offers sensitized patients a cheaper option to reduce their exposure to bio-contaminants in their bed. If used in addition to other allergen-avoidance methods, such as mattress encasings and regular washing of bedding items, it might reduce their exposure even further. In our study, none of the participants used mattress encasings and, unfortunately, no information on bedding washing was obtained. Compliance to allergen-avoidance methods is generally poor (30) and therefore patients may not comply with daily vacuuming of their mattress, despite its low cost. It has, however, been shown that either providing house dust mite proof covers or home visits by a counselor greatly improves compliance with house dust mite allergen-avoidance strategies and are viable options (30, 31).

Further studies are required to determine whether these reductions have a long-term clinical benefit and whether prolonging the daily vacuuming beyond the 8 weeks of this study further reduces their exposure. Vacuum cleaners, including high-efficiency particulate-arrest-filter models, leak allergens thus increasing personal house dust mite allergen exposure either during vacuum cleaning or emptying of the vacuum cleaner bag (32). However, it is generally recommended that house dust mite-sensitized patients do not vacuum themselves and have nonsensitized persons do the vacuum cleaning and do not enter the room being vacuumed for at least half an hour after which all airborne dust will have settled.

It is also not known whether other indoor allergens found in bedding, such as Fel d 1 (cat) and Can f 1 (dog) will also be reduced by daily vacuuming as we did not analyze the dust samples for these allergens. However, given that the average total dust weight recovered reduced by nearly 80% after 8 weeks of daily vacuuming, it is expected that any cat and dog allergen present would also be significantly reduced. It has, however, previously been shown that long-term weekly vacuuming of mattresses significantly decreases Fel d 1 and Can f 1 levels (17). It would also be of interest to determine whether the achieved reductions in the mattress effects their levels in bedding, such as duvets and pillows, given that pillow and duvet allergen levels are determined by the mattress environment (20, 33).

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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