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Research Article

Deposition Rates of Asthma Triggers on Conventional and Enclosed Window Treatments

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Abstract

Environmental interventions are an important element of managing allergies and asthma. Health professionals often recommend that draperies be replaced with window blinds however no data exist on accumulation of inhalant allergens or inflammatory bioaerosols on window treatments. Installing blinds that accumulate less dust may reduce breathing zone exposures when blinds are adjusted if hazardous amounts of bioaerosols are deposited. We sought to determine the rate of accumulation of dust, allergens, bacterial endotoxin and fungal glucan on window blinds of two distinct types mounted on the two types of windows most commonly installed in U.S. homes. The blinds tested were conventional horizontal slat blinds hanging on the inside of the window (room-side blinds) and similar blinds placed between the exterior window glass and an extra pane of glass on the interior side (between-glass blinds). The study was conducted in six households as a paired, repeated measures study. Households were identified for participation, having met the study criteria of children and cats living inside a carpeted home. Standard window blinds accumulated cat allergen, endotoxin and fungal glucan at rates of 5940ng/m^2, 1910EU/m^2, and 11,360ng/m^2 per month. Between-glass blinds reduced the loading of asthma triggers by 25- to 185-fold. Comparison with clinical thresholds associated with asthma morbidity indicates that room-side blinds accumulate potentially hazardous quantities of asthma triggers.

Keywords: Allergens; Asthma triggers; Bioaerosols; Endotoxin; Glucans; House dust

Abbreviations

ANOVA: Analysis of Variance; ELISA: Enzyme-Linked Immunosorbent Assay; EU: Endotoxin Unit; Fel d1: Felis Domesticus 1 (Cat allergen); GM: Geometric Mean; NHANES: National Health and Nutrition Examination Survey; NSLAH: National Survey of Lead and Allergens in Housing; PBS: Phosphate-Buffered Saline; PF: Pyrogen Free (Free of Endotoxin).

Introduction

Asthma and wheeze are common adverse respiratory outcomes triggered by exposures to house dust containing inhalant allergens such as those from mites, cockroaches, molds and pets, and inflammatory bioaerosols acting as microorganism-associated molecular patterns, especially bacterial endotoxin and fungal glucans [1-3]. Endotoxin interacts through CD-14, MD-2 and TLR-4 [4] while β-glucan acts through dectin-1 and TLR-2 [5]. Additionally, endotoxin exposure is associated with the development of chronic obstructive pulmonary disease [6]. Interventions in homes often seek to lower allergens and endotoxin through pet avoidance, institution of integrated pest control, replacement of carpeted floors with cleanable surfaces, installation of high efficiency air filtration and limiting clutter to enhance ease of cleaning [7]. In addition, it is often suggested that draperies and curtains be replaced with window blinds or shades [8,9].

Many studies have examined levels of endotoxins and allergens on floors, beds and upholstery. Two large, nationally representative studies are the National Survey of Lead and Allergens in Housing (NSLAH) and the 2005-2006 rounds of the National Health and Nutrition Examination Survey (NHANES) [1-3,10]. These are the largest studies conducted to date that evaluated exposures to allergens and endotoxin and assessed respiratory outcomes. Additionally, NHANES included serological evaluation of specific IgE directed toward 15 inhalant allergens [11].

While prior studies have evaluated allergen and endotoxin loads on carpets, sofas, bedding, kitchen floors, and bookcases [1,3,12,13], no studies have evaluated window treatments. Specifically, the rate of deposition of allergens and inflammatory agents on window blinds has not been studied and it is not established whether the rate of accumulation differs between types of windows and window treatments. In order to develop evidence-based recommendations for the selection of window treatments for patients with asthma and allergy and to aid in exposure assessment for causal agents, we determined the rate at which cat allergen and microbial agents deposit on two types of window blinds on both casement and double-hung windows. The blinds tested were conventional horizontal slat blinds hanging on the inside of the window (room-side blinds) and a newer type of blind that is placed between the exterior window glass and an extra pane of glass on the interior side (between-glass blinds).

Materials and Methods

This study was conducted as a paired, repeated measures study of

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the deposition of dust, allergens, endotoxin and glucan on two types of blinds mounted on two types of windows. Six households were identified for participation, having met the study criteria of children and cats living inside a carpeted home. Each agreed to host a window assembly for three months and to allow us to enter their home for the purpose of collecting samples. Sampling occurred from December through February.

Three identical twin casement window units and three identical twin double-hung window units were studied (Designer Series, Pella Corp, Pella, IA) as illustrated in Figure 1. Each unit contained one window with standard aluminum horizontal room-side window blinds, and an identical adjoining window with between-glass window blinds of the same construction (Designer Series, Cordless, Slimshade Blinds, Pella Corp). Each window within the window assembly was 53.3cm by 88.9cm (21 in x 35 in). The window assemblies were placed in homes on a custom-built stand such that the base of the windows stood at a height of 1m above the floor and the windows were held vertically against a wall in a high-traffic, carpeted area. Participants were instructed not to touch or move the window assembly.

Prior to the study, electrostatic wipes and medical examination gloves were tested to establish that they were low in endotoxin as previously described [14]. Wipes for sampling were handled using sterile technique and were cut into 5 cm by 5cm squares from unscented electrostatic cloths (Pledge Grab-it Mitts, SC Johnson and Son, Racine, WI). They were weighed using an ultramicrobalance (Mettler-Toledo MT-5, Columbus, OH). Upon installation, each window blind was thoroughly cleaned with an endotoxin-free, electrostatic wiping cloth to remove any dust, endotoxin and allergen that might be present. The blinds were released to encompass the area of the glass, and the slats were adjusted to a horizontal position (parallel to the floor) for optimal dust collection.

At one-month intervals after window placement, samples were collected from the blinds using pre-weighed, pyrogen-free (PF), electrostatic wiping cloths while wearing PF powder-free Latex medical examination gloves (Safe Skin-PEF, Kimberly-Clark, Dallas, TX). Samples were collected by wiping each slat from right to left, top to bottom, beginning with the room-side blinds. New gloves were used for each window. Wipe samples were placed in bar-coded, PF extraction vials for transfer to the laboratory. Samples were post-weighed and eluted into 5ml PF water with 0.05% Tween-20, shaken for 1h, centrifuged at 600xG at 4°C for 20min, and 500µl of the supernatant was transferred to another tube for endotoxin assay. To 4500µL of the supernatant we added and vortexed 500µl of 10x Phosphate Buffered Saline (PBS) with 0.05% Tween-20 for analysis of Fel d1. The pellets were re-eluted in PBS with 0.05% Tween-20, shaken for 1h, autoclaved for 1h at 120°C, shaken for another 15min and centrifuged at 600xG, 4°C for 20min. The supernatant was then transferred to another tube and assayed for glucan.

Samples were analyzed for endotoxin using the kinetic chromogenic Limulus Amebocyte Lysate (LAL) assay [3,15]. Samples were analyzed for Fel d1 using enzyme immunoassay (Indoor Biotechnologies, Charlottesville, VA). Glucan was assayed using a monoclonal antibody specific for (1*3)-b-D-glucan in PBS and 1% bovine serum albumin in PBS with 0.05% Tween-20. A custom rabbit polyclonal anti-(1*6) branched, (1*3)-b-D-glucan antibody was used for detection followed by incubation with conjugated goat anti-rabbit IgG-HRP and TMB [16-18].

Results and Discussion

Overall, the geometric mean one-month accumulation per unit area of endotoxin, Fel d1, and fungal glucan on the room-side blinds was 1910EU/m^2, 5940ng/m^2 and 11,360ng/m^2, respectively. These values for the between-glass blinds were 37.1EU/m^2, 28.2ng/m^2 and 804ng/m^2, respectively. In comparison, in the NSLAH study we measured geometric mean loading in family room floor dust of 17,600EU/m^2 for endotoxin and 342ng/m^2 for cat allergen [1,2,10]. However, since vacuum-sampled floor dust is not as readily released to the air as is dust on window blinds, this makes the high cat allergen loading on the room-side blinds even more remarkable.

Comparison of wipe samples collected on all three visits demonstrated a highly significant difference in loading of the endotoxin, Fel d1 and fungal glucan of the between-glass blinds when compared with the room-side blinds (Figure 2). The average ratio of room-side to between-glass blinds for the accumulation of endotoxin was 25-fold and 52-fold for the casement and double-hung windows, respectively. Cat allergen demonstrated a ratio of 185-fold for both and, for fungal glucans, a ratio of 12-fold and 16-fold were observed (Table 1 and Figure 2). Analysis of variance (ANOVA) showed a highly significant difference ($p<0.0001$) for endotoxin, Fel d1 and fungal glucan with type of blind but not with window type (Table 1). Only endotoxin showed a significant effect of window type on accumulation rate ($p=0.011$) with the double-hung window accumulating more endotoxin. There was no significant interaction of blind and window type and ANOVA for repeated measures showed no effect of month of sampling on the levels of analytes on the blinds.

Figure 2 shows clearly that between-glass blinds accumulated far less dust, endotoxin, cat allergen and glucan than conventional room-side blinds. From these values we can determine that if one were to release the 1-month accumulation of endotoxin, Fel d1 or fungal glucan by raising or agitating the blinds, the average room-side blind would release up to 516EU of endotoxin, 1570ng of Fel d1, 3040ng of

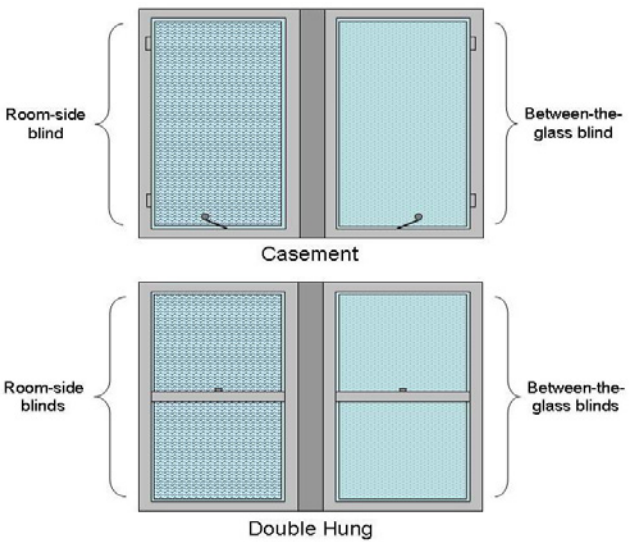

Figure 1: Window and blind types tested.

Table 1: Average monthly dust loading and analyte accumulation per unit area for room-side and between-glass blinds for each window type. Geometric mean (10th, 90th percentile) values are shown for each of the analytes.

Window	Blind	Analyte GM (10th, 90th percentile)		
		Endotoxin EU/m²	Fel d1 ng/m²	Fungal Glucan ng/m²
Casement	Room-side Blind	1,420 (731, 3410)	7,320 (407, 133000)	8,750 (2250, 44700)
	Between-glass Blind	27.7 (15.8, 51.9)	39.6 (16.5, 43.8)	714 (431, 1162)
	Ratio†	25-fold	185-fold	12-fold
Double Hung	Room-side Blind	2,566 (2060, 3420)	4,814 (895, 24800)	14,740 (10100, 56100)
	Between-glass Blind	49.6 (24.3, 81.5)	25.9 (8.8, 137)	906 (418, 1350)
	Ratio†	52-fold	185-fold	16-fold
ANOVA p value*	Blind Type	<0.0001	<0.0001	<0.0001
	Window Type	0.011	0.36	0.2

†Ratio of Room-side to between-glass blinds.
*ANOVA Model: Loge [Analyte] = ß0+ß1•Blind+ß2•Window+ ß3•Window x Blind + ξ.
None of the interactions were significant.

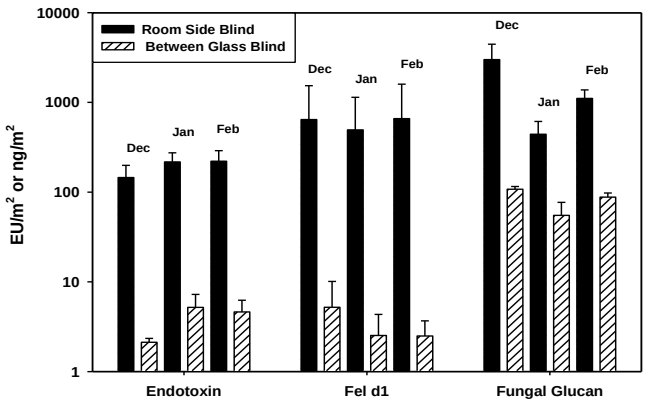

Figure 2: Monthly window blind loading per unit area for endotoxin (EU/m²), Fel d1 (ng/m²), and fungal glucan (ng/m²) on two types of blinds. Geometric mean values are shown for each monthly visit. Error bars indicate geometric standard error.

glucan, and 7760µg of dust. In most homes with typical air exchange rates, these levels would be sufficient to induce airway inflammation and trigger allergic symptoms in atopic asthmatics. The clinical threshold associated with asthma morbidity for Fel d1 measured by ELISA is 8µg/g [19]. Here we measured 1570ng Fel d1 in 7760µg of dust which equates to 202µg Fel d1/g of dust, or 25-fold higher than the clinical threshold for increased asthma morbidity. Similarly, the potential endotoxin concentration of 66.5EU/mg (516EU per 7760µg of dust) far exceeds the geometric mean endotoxin concentration found in the 6963 homes measured in the NHANES of 15.49EU/mg [3].

These values above contrast sharply with the average between-glass blinds which would release less than 10EU of endotoxin, 8.5ng of Fel d1, 210ng of glucan and less than 35µg of dust. Thus, between-glass blinds could reduce exposures to these recognized asthma-triggering agents. We suggest that this type of blind should be considered as part of an extensive indoor intervention for asthmatic individuals of people with severe allergy to household inhalant allergens such as from cats, dogs, mice, mites, cockroaches, or molds.

Conclusion

This study demonstrates that standard window blinds accumulate bioaerosols such as bacterial endotoxin, fungal glucans and cat allergen at a surprisingly high rate and that agitation of the blinds could result in significant exposures to these biological agents. Newer window styles that encase blinds between glass panes accumulate relatively small amounts of dust and bioaerosols and therefore represent an effective intervention for people who suffer with allergy or asthma.

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