

Mattress risk factors for the sudden infant death syndrome and dust-mite allergen (der p 1) levels

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ABSTRACT

Allergen-induced anaphylaxis has been suggested as a possible etiology for sudden infant death syndrome (SIDS). Some of the measures recommended for reducing the risk of allergen exposure also are recommended for reducing the risk of SIDS. The purpose of this study is to evaluate possible associations between dust-mite allergen (der p 1) levels within cot (crib) mattresses and established cot mattress risk factors for SIDS. Dust from polyurethane foam was extracted from two regions of used cot mattresses donated by 28 households in Leicester (United Kingdom) and der p 1 allergen levels estimated using a two-site monoclonal antibody system. Infant and cot environment-related factors were determined via parental questionnaire. For the infants' head region of the mattresses, the following associations were independently significant following multivariate analysis: quantity of dust extracted, with older mattresses ($p = 0.014$); high allergen concentrations (der p 1 per mg dust), with high frequency of minor ailments ($p < 0.001$) and older infants ($p = 0.044$); and high total der p 1 content, with high frequency of minor ailments ($p = 0.014$). There were no independently significant associations between levels of der p 1 in polyurethane foam and the established cot mattress risk factors for SIDS. Although der p 1 accumulates within polyurethane foam of cot mattresses with use over time, this does not provide a valid mechanistic explanation for the established cot mattress-related risk factors for SIDS. There is an association between der p 1 levels of cot mattress polyurethane foam and frequency of minor ailments; additional research is required to establish cause and effect.

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Allergen-induced anaphylaxis has been suggested as a possible etiology for sudden infant death syndrome (SIDS).¹ Studies on this hypothesis have focused on the presence of antibodies in the serum of SIDS infants compared with those of control infants, with mixed findings. Turner *et al.*² reported an elevation in specific antibodies to the dust mite *Dermatophagoides pteronyssinus*, β -lactoglobulin, and *Aspergillus fumigatus* in 54 SIDS victims compared with 27 living and dead controls aged <20 months old. Other investigators have reported no significant differences in antibodies to these three allergens³ or to tryptase and allergen-specific IgE in the serum of SIDS infants compared with age-matched control cases of sudden death of known cause.⁴ Buckley *et al.*,⁵ however, reported elevated β -tryptase but no increase in α -tryptase or allergen-specific IgE. β -Tryptase has been found in high con-

centrations in the serum of adult patients with anaphylaxis.⁶

Several studies provide evidence of a link between SIDS and cot mattresses. There is an increased risk of SIDS associated with (1) sleeping on older mattresses not completely covered in polyvinyl chloride (PVC)⁷ and (2) routine use of an infant mattress previously used by another child.⁸ Mattresses with exposed polyurethane foam and previous use of these types of mattresses by another child have been shown to be significantly associated with increased frequency of isolation of *Staphylococcus aureus* from cot mattress polyurethane foams,⁹ which in the context of the common bacterial toxins hypothesis for SIDS¹⁰ could explain the lowered risk of SIDS associated with use of water-impermeable mattress covers.^{11,12}

Some of the measures recommended for reducing the risk of allergen exposure also are recommended for reducing the risk of SIDS. Using new mattresses, blankets, and top plastic sheets and/or mite-impermeable bedding have been shown to be effective in reducing dust-mite exposure,^{13,14} and the Foundation for the Study of Infant Deaths¹⁵ recommends the use of a cot mattress that was made with a completely waterproof cover. However, little guidance is given by the American Academy of Pediatrics' Task

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Force on SIDS,¹⁶ who simply advises using a firm crib mattress covered by a sheet.

Differential exposure to dust mites or other ubiquitous allergens is a plausible mechanistic explanation for the established cot mattress-related risk factors for SIDS. The purpose of this study was to test this possibility by evaluating dust-mite allergen levels associated with polyurethane foams of used cot mattresses in relation to sleeping practice, home environment, and infant health.

METHODS

Cot Mattress Collection and Donor Questionnaire

Used polyurethane foam cot mattresses (28) were donated by members of parent and toddler groups in the Leicester (United Kingdom) area and categorized according to mattress type and previous use: integral or nonintegral; previously used or not previously used. Integral cot mattresses were completely covered with PVC. Previously used cot mattresses had been used by another child in the same household; not previously used mattresses had been used by one child only. All mattresses were purchased new by the donating household and were in use immediately prior to donation.

A mattress donor questionnaire was used to provide details of infant sleeping practice, home environment, and infant health: age of the last infant to use the mattress at time of the last sleep on mattress, gender, number of minor ailments (*i.e.*, infections indicated by runny nose and fever), smoking within the household (mother and/or father smoked daily), period of breastfeeding, age of mattress, previous use of mattress by another child, double glazing in the cot room (*i.e.*, two layers of glass with vacuum between), type of bedding (sheets) used to cover the mattress (cotton, flannel/towelling sheet, and other), and usual sleeping position of the infant (back, side, and front).

Dust Collection and Determination of Dust-Mite Allergen Concentration

Dust samples were collected from the polyurethane foam at two sites on the cot mattress, according to the usual sleeping position of the infant (head or torso). Dust samples were taken from the surface of the mattress by vacuuming according to Mahrshahi *et al.*¹⁷ A 12.5-cm² section of polyurethane foam was vacuumed for 5 minutes and a new nylon vacuum bag was used for each sample. Collected dust was sieved through a 300- μ m mesh wire sieve, weighed, and stored at 4°C before analysis. The vacuum cleaner head was cleaned in 5% disinfectant solution with high surfactant activity (Virkon, Russel Mainstream Supply, Ltd., Fife, U.K.) rinsed in distilled water and air-dried after each sample was taken.

Dust-mite allergens from each dust sample (10 mg of dust in 2 mL of buffer) were extracted into borate-buffered saline (25 mM of sodium borate, 100 mM of boric acid, 75 mM of NaCl, and 5 mM of disodium EDTA, pH 8.0). The der p 1 content of each extract was estimated using the two-site (5H8/4C1) monoclonal antibody system (Indoor Biotechnologies, Ltd., Manchester, U.K.) according to Luczynska *et al.*¹⁸ Absorbances were measured on a Multiskan MCC/340 plate reader at a 405-nm wavelength.

Bacterial Counts

Triplicate 1-cm³ sections of polyurethane foam were removed from each mattress sampling point before the collection of dust samples. The bacterial population at each site was extracted by 10 minutes of rotary incubation in 2.5 mL of physiological saline (0.85% sterile NaCl) followed by 45-second vortex mixing and 30-second agitation with a sterile glass rod.⁹ Viable counts (CFU cm⁻³ polyurethane foam) were taken from each extraction mixture by serial dilution to 10⁻⁴ and plating onto nutrient agar (Oxoid, Basingstoke, U.K.). Plates were incubated aerobically at 33°C for 48 hours.

Data Analysis

Data were analyzed with SPSS software, version 14.0 (SPSS, Inc., Chicago IL). Univariate comparison of means for each parameter (*e.g.*, der p 1 per milligram of dust from mattresses from homes with double glazing in the cot room, compared with mattresses from homes without double glazing in the cot room) was performed using a two-tailed Student's *t*-test; the Kolmogorov-Smirnoff test was used to confirm Gaussian distributions. Multivariate analysis was performed using a general linear model that provided regression analysis and analysis of variance for multiple-dependent variables (*i.e.*, mean dust recovered, mean der p 1, and mean total der p 1) by the various parameters (*i.e.*, those shown in Tables 1 and 2). Differences were considered to be statistically significant when $p < 0.05$.

RESULTS

Data on infant- and mattress-related factors were obtained from parents donating cot mattresses for the study by means of a questionnaire. The factors investigated were infant age, gender, ailments (runny nose and fever), sleeping position, smoking within the household, breast or bottle feeding over the first 16 weeks, age of mattress, double glazing in the cot room, and type of bedding (sheets) used. Infant age was the age of the last infant to use the mattress at the time of last sleep on the mattress: range, 18–173 weeks; median, 91.0 weeks; interquartile range, 58.75 weeks. Sleeping position was the usual sleeping position of

Table 1 Dust and mite allergen (der p 1) recovered from the infants' head sample region of used cot mattresses.

Parameters	Number of Mattresses Sampled (n)	Mean Dust Recovered (mg)	Mean der p 1 ($\mu\text{g mg}^{-1}$ dust)	Mean Total der p 1 (μg)
Integral vs NI mattresses	8 20	11.7 (6.1) 32.7 (20.8) $p = 0.008$	4.7 (6.6) 14.3 (16.4) $p = 0.12$	64.3 (122.1) 165.5 (247.1) $p = 0.32$
NPU vs PU mattresses	14 14	17.3 (9.9) 35.9 (23.5) $p = 0.01$	5.2 (8) 17.9 (17.2) $p = 0.018$	128 (243.7) 788.1 (988.7) $p = 0.022$
Infant gender				
Male	20	27.2 (22.8)	11.2 (15.7)	487.8 (871.8)
Female	8	25.1 (12) $p = 0.88$	12.4 (12.7) $p = 0.90$	383.6 (538.2) $p = 0.76$
Infant age				
<1 yr vs	12	16.3 (13)	2.8 (5.2)	65.4 (186.5)
>1 yr	16	34.3 (21.3) $p = 0.016$	18.2 (16.2) $p = 0.004$	752.5 (927.7) $p = 0.018$
Infections				
<6	20	22.7 (20.6)	4.5 (5.8)	137.6 (303.7)
>6	8	36.3 (16) $p = 0.108$	29.3 (15.6) $p = 0.000001$	1259.2 (1041.2) $p = 0.0001$
Smoking household				
Yes	8	24.6 (21.4)	12.3 (14.7)	456.3 (755.6)
No	20	31.6 (16.5) $p = 0.42$	9.7 (15.6) $p = 0.68$	462.5 (900.9) $p = 0.96$
Breastfed				
>16 wk	12	30.1 (27)	12.8 (14.3)	570.8 (849.8)
<16 wk	16	24 (13.2) $p = 0.44$	10.7 (15.4) $p = 0.70$	373.4 (744.7) $p = 0.52$
Mattress age				
<5 yr	22	23.3 (19.6)	7.6 (9)	242.7 (366.8)
>5 yr	6	38.7 (18.2) $p = 0.10$	26 (22.6) $p = 0.004$	1247.5 (1337.6) $p = 0.003$
Double glazed cot room				
Yes	16	32.6 (22.9)	14.8 (16.1)	631.2 (927.2)
No	12	18.6 (12.4) $p = 0.06$	7.3 (12) $p = 0.18$	227.2 (478.1) $p = 0.18$
Cotton vs Flannel/towelling sheet	15 13	19.9 (12.5) 33.5 (25.5) $p = 0.08$	8 (9.6) 16.6 (19.2) $p = 0.14$	202 (294.2) 797.7 (1082.7) $p = 0.05$
Bacteria*				
< 4.0×10^4	13	19.9 (15.3)	12.2 (17.2)	457.3 (883.9)
> 4.0×10^4	15	32.5 (22.3) $p = 0.10$	11.1 (12.8) $p = 0.84$	458.7 (714.9) $p = 1.00$
Prone vs Other sleeping positions	9 19	35.7 (44.3) 13.3 (9.2) $p = 0.04$	18.4 (30.9) 5.7 (6) $p = 0.10$	451.9 (552.6) 91.2 (184.8) $p = 0.015$

The p values are univariate analysis probabilities. Values in parentheses are SDs for the means.

*Total bacterial counts (CFU cm^{-3}) for polyurethane foam of cot mattresses.

PU = mattress previously used by another child; NPU = mattress not previously used by another child; NI = nonintegral mattress (not completely covered with PVC).

Table 2 Dust and mite allergen (der p1) recovered from the infants' torso region of used cot mattresses

Parameters	Number of Mattresses Sampled (n)	Mean dust Recovered (mg)	Mean der p 1 ($\mu\text{g mg}^{-1}$ dust)	Mean Total der p 1 (μg)
Integral vs	8	16.7 (10)	2.9 (1.2)	40.9 (30)
NI mattresses	20	22.1 (32)	12.6 (21.4)	273.7 (431.4)
		$p = 0.32$	$p = 0.22$	$p = 0.14$
NPU-NI vs	8	16.8 (16.9)	7.4 (5.3)	163.4 (218.3)
PU-NI mattresses	12	25.6 (39.4)	16 (27.3)	347.1 (525.7)
		$p = 0.56$	$p = 0.40$	$p = 0.36$
Infant gender				
Male	20	20.6 (31.9)	10.1 (6.2)	204.5 (273.0)
Female	8	20.3 (9.2)	18.2 (33.3)	213.8 (576.6)
		$p = 0.98$	$p = 0.45$	$p = 0.48$
Infant age				
<1 yr	12	11.8 (9.5)	3.6 (2.4)	35.4 (40.2)
>1 yr	16	27.1 (34.4)	14.5 (23.7)	336.0 (462.9)
		$p = 0.14$	$p = 0.12$	$p = 0.034$
Infections				
<6	20	19.6 (31.8)	5.1 (4.0)	104.1 (203.7)
>6	8	22.8 (12.2)	21.4 (32.6)	464.9 (575.6)
		$p = 0.80$	$p = 0.032$	$p = 0.019$
Smoking household				
Yes	8	14.5 (6.8)	5.9 (4.4)	87.1 (86.0)
No	20	23.0 (32.1)	11.4 (21.7)	255.2 (437.6)
		$p = 0.48$	$p = 0.50$	$p = 0.30$
Breastfed				
>16 wk	12	24.6 (40.3)	6.7 (6.4)	186.2 (317.2)
<16 wk	16	17.4 (11.7)	12.1 (24.0)	222.9 (427.0)
		$p = 0.50$	$p = 0.46$	$p = 0.80$
Mattress age				
<5 yr	22	22.8 (30.2)	9.7 (20.6)	213.1 (398.9)
>5 yr	6	12.2 (10.9)	10.2 (8.2)	185.3 (318.3)
		$p = 0.40$	$p = 0.96$	$p = 0.88$
Double glazed cot room				
Yes	16	23.9 (35.4)	13.5 (23.4)	283.7 (450.2)
No	12	16.0 (9.9)	4.8 (6.8)	105.0 (232.0)
		$p = 0.46$	$p = 0.22$	$p = 0.22$
Cotton	15	16.3 (13.2)	11.2 (24.9)	208.7 (445.9)
Flannel/towelling sheets	13	26.4 (39.5)	8.6 (7.1)	218.1 (307.8)
		$p = 0.36$	$p = 0.74$	$p = 0.94$
Bacteria*				
$<1.5 \times 10^4$	13	11.7 (8.9)	5.1 (4.3)	49.4 (51.5)
$>1.5 \times 10^4$	15	28.2 (35.3)	13.9 (24.7)	343.9 (479.3)
		$p = 0.12$	$p = 0.20$	$p = 0.036$
Prone sleeping vs	9	13.6 (11.6)	5.9 (4.9)	97.7 (137.3)
Other sleeping positions	19	23.8 (32.1)	11.7 (22.2)	259.0 (443.6)
		$p = 0.36$	$p = 0.46$	$p = 0.30$

The p values are univariate analysis probabilities. Values in parentheses are SDs for the means.

*Total bacterial counts (CFU cm^{-3}) for polyurethane foam of cot mattresses.

PU = mattress previously used by another child; NPU = mattress not previously used by another child; NI = nonintegral mattress (not completely covered with PVC).

the infant during the months/weeks before the mattress donation.

Data on dust and dust-mite allergen recovered from the infants' head region of cot mattresses are shown in Table 1. By univariate analysis, the following factors were shown significantly ($p < 0.05$) associated with high dust levels at the infants' head region of cot mattresses: use of nonintegral mattresses, previous use of mattresses by another child, older infants, and prone sleeping. By multivariate analysis, only use of older mattresses was shown to be independently significant with respect to dust levels ($p = 0.014$). Three of these factors—previous use of mattresses by another child, older infants, and use of older mattresses—were also significantly ($p < 0.05$) associated with high der p 1 levels at this sample site, by univariate analysis. Only one additional factor—high frequency of minor ailments—was significantly associated with high der p 1 levels, while not being significantly associated with high dust levels at the sample site. By multivariate analysis, high frequency of minor ailments ($p = 0.001$) and older infants ($p = 0.044$) were shown to be independently significant with respect to concentration of der p 1 in dust. Only high frequency of minor ailments was independently significant ($p = 0.014$) with respect to total der p 1 levels at the sample site.

The following factors were shown by univariate analysis not to be significantly associated ($p > 0.05$) with either dust levels or mite allergen levels at the infants' head sample region of cot mattresses (Table 1): infant gender, smoking in the household, breastfeeding, double glazing in the cot room, use of cotton sheets, and high bacterial counts for the polyurethane foam. Data on dust and dust-mite allergen recovered from the infants' torso sample region of cot mattresses are shown in Table 2. By univariate analysis, none of the factors tested were significantly ($p > 0.05$) associated with high dust levels, while only one factor—high frequency of minor ailments—was significantly ($p = 0.032$) associated with high concentrations of der p 1 in dust. Regarding total levels of der p 1 at the sample site, the factors shown to be significantly ($p < 0.05$) associated by univariate analysis were older infants, high frequency of minor infections, and high bacterial population density within polyurethane foams. None of the factors tested showed independent significance ($p > 0.05$) for der p 1 levels by multivariate analysis.

DISCUSSION

The two most important risk factors for SIDS are sleeping in the prone position and exposure to cigarette smoke.^{7,18} In this study, neither of these factors was associated with increased der p 1 at the infants' head region of cot mattresses. Although there was no direct association, prone sleeping could indirectly in-

crease exposure to dust-mite allergens through proximity of the respiratory tract, and smoking could increase infant susceptibility to dust-mite allergens through sensitization.

Recently, we have reported significantly higher bacterial populations associated with polyurethane foams from nonintegral mattresses when compared with those from mattresses completely covered by PVC.⁹ Although dust-mite allergen levels associated with polyurethane foams also might be expected to be influenced by mattress type, the data reported here did not reveal any significant association ($p > 0.05$). This is consistent with the findings of Tempels-Pavlica *et al.*²⁰ who reported on a "remarkably small" decrease in der p 1 levels arising from use of a mite-impermeable cover on mattresses.

Routine use of an infant mattress previously used by another child has been reported to be associated with an increased risk of SIDS.⁸ In this study, although use of mattresses by another child was associated with increased der p 1 levels at the infants' head region of cot mattresses, independent significance was not shown. Nevertheless, the independently significant associations for dust-mite allergen levels at the infants' head region of the mattresses with older infants is consistent with accumulation of allergens in polyurethane foam with use over time. Because the majority of SIDS cases occur in infants aged 2–4 months,²¹ exposure to elevated der p 1 levels of cot mattress polyurethane foams would not normally coincide with the period of greatest susceptibility to SIDS. However, on a mattress previously used by another child, a second infant could be exposed to elevated der p 1 concentrations during the most vulnerable age.

Symptoms such as runny noses and slight fevers have been associated with both sensitization to dust-mite allergens and SIDS. Peat and Woolcock²² reported an increased risk of bronchial hyperresponsiveness and asthma in children sensitized to house-dust mite allergens. At least 50% of SIDS victims have respiratory or gastrointestinal infections before death.^{23,24} In the work reported here, there was a highly significant independent association between dust-mite allergen levels at the infants' head region of mattresses and the number of minor ailments suffered by an infant. Increased exposure to dust-mite allergens could promote induction of an inflammatory response that would increase congestion in the upper respiratory tract, a condition that some researchers have suggested may be associated with SIDS.²⁵

The data reported in this study suggest that dust-mite allergens accumulate in polyurethane foams of cot mattresses with use over time. Although the possibility that this might be a contributing factor to an immunopathological response in some SIDS cases can not be excluded, the apparent lack of statistically significant

associations suggests that levels of dust-mite allergens in cot mattress polyurethane foams do not provide a valid mechanistic explanation for the cot mattress-related risk factors^{7,8} for SIDS.

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