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ALLERGY

## Original article

# Concentrations of domestic mite and pet allergens and endotoxin in Palestine

**Background:** A few studies have compared indoor allergens and endotoxin levels between urban and rural settings as important determinants for asthma and atopy in children. However, no study was done in the Middle East or investigated refugee camps.
**Methods:** As part of a nested case–control study in Ramallah in 2001, we measured house dust mite and pet allergens, as well as endotoxin in dust collected from 110 children's mattresses and living room floors.
**Results:** Geometric mean (GM) concentrations of *Dermatophagoides pteronyssinus* (Der p1) antigen were 4.48 μg/g in mattress dust and 1.23 μg/g floor dust. The highest Der p1 levels were seen in refugee camps. Concentrations of *Dermatophagoides farinae* antigen (Der f1) were much lower ( < 0.08 μg/g dust). Concentrations of cat allergen (Fel d1) were highest in villages, and those of dog allergen (Can f1) were highest in mattresses from cities and in floor dust from refugee camps. GM of endotoxin levels were 25.7 EU/mg in mattress dust and 49 EU/mg dust in floor dust.
**Conclusions:** Concentrations of Der p1 were high compared to Western European countries, but were lower compared to UK and Australia. Levels of pet allergens were lower than in Western Europe. Endotoxin levels were higher compared to developed countries. Indoor environmental factors such as dampness seemed to be important determinants for allergen and endotoxin, but living habits such as lack of mattress cover appeared unimportant.

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Key words: endotoxin; environment; home; mites; Palestine; pets.

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A limited number of studies point toward positive relationships between the occurrence and the intensity of asthma and allergy in children, on the one hand, and housing characteristics, including the intensity of contamination by domestic allergens or other agents, such as bacterial endotoxin, on the other (1). Several studies have been done in this field in Western developed countries, but little information is available from developing countries, particularly in the Middle East (2, 3).

In a cross-sectional questionnaire study conducted among 3382 children from the Ramallah district of Palestine, we found that the prevalence of 12-month wheezing amounted to 8.2, 7.2 and 12.6% for children residing in villages, cities and refugee camps, respectively (4). This cross-sectional study was followed by a case–control study (5), in which the homes of a selected sample of children were visited for dust collection. The present article examines the influence of residential characteristics and living habits on concentrations of mite and pet allergens and endotoxin in Palestinian houses. These findings will be used to help explore the possible association between indoor environmental exposures and asthma in Palestinian children.

## Materials and methods

### The selection of homes and study location

The selection of homes, the study location, the participation rate and the ethical approval of this case–control study have been described previously (5). From this case–control study (5), we randomly selected 132 children to have a home visit with a collection of domestic dust. Forty four children (22 cases and 22 controls) were selected randomly from each type of locality, i.e. cities, villages and refugee camps. However, we were able to collect samples in only 110 homes. The definitions of urban, rural or village and refugee camp are according to the Palestinian Center Bureau of Statistics (PCBS). Urban refers to all localities whose populations vary from 4000 to 9999 persons provided they have at least four of the following elements: public electricity network, public water network, post office, health center with a full-time physician and a school offering a general secondary education certificate. Rural refers to any locality with the same population size but which lacks most of the aforementioned elements. Refugee camp refers to any locality administered by the United Nations Refund Work Agency in the Near East (UNRWA).

This study is part of the International Study for Asthma and Allergy in Childhood (ISAAC) phase II (6).

### Questionnaire on indoor exposures and residential characteristics

The ISAAC phase II risk assessment questionnaire included questions related to living habits and indoor housing characteristics, such as type of window glass, type of carpets and mattresses, presence of molds and/or damp spots, fuel used for heating and cooking and smoking in the home (4). An additional observational questionnaire was filled in by the investigators during home visits to document environment-related data, such as distance between houses and distance from farm-animals, and living habits factors, such as method and frequency of cleaning the floor, use of mattress covers and frequency of washing bed sheets.

### Field work, house dust extraction and analysis

A week before the home visit, families were asked not to clean the index child's sheets or living room floors at least 3 days prior to our visit, in order to allow enough material to settle. In each house, two dust samples were collected: one from the index child's sleeping mattress and one from the floor of the living room. In five houses, only one sample was collected from the mattress because the child slept in the living room and the family used the same sleeping mattress for seating. The mattress concentration result for these five children with one sample was also used for their floor dust concentration.

The dust collection on glass filter paper was done using an internationally standardized protocol (7). All samples were collected within 3 weeks in April 2001, at temperatures between 11 and 17°C and 45–60% relative humidity, as reported in the weather broadcasting during that period (The National newspaper, *Al Quds* daily newspaper).

Endotoxin and allergens were extracted from the dust as described previously (7, 8). Dust extracts were analyzed for allergens typical of house dust mites (Der p1 from *Dermatophagoides pteronyssinus*, and Der f1 from *Dermatophagoides farinae*), cat (group 1 allergen, Fel d1 from *Felis domesticus*), and dog (group 1 allergen, Can f1, from *Canis familiaris*) using a monoclonal enzyme-linked immunosorbent assay as prescribed previously (9). The average detection limits of the assays were 4.30 ng/ml for Der p1, 2.60 ng/ml for Der f 1, 0.60 ng/ml for Fel d1, and 2.70 ng/ml for Can f1. Two Der p1, six Fel d1 and four Can f1 measurements were below the detection limits. These samples were assigned values equal to two-thirds of the relevant detection limit.

Samples extracted for measuring endotoxin were quantified using a chromogenic kinetic *Limulus* amebocyte lysate assay, as described previously (7). In addition to 10% of randomly selected samples, samples with concentrations lower than two-thirds of the lower limit of maximum velocity or greater than the upper limit of maximum velocity were analyzed again with additional dilutions depending on their concentrations. The average detection limit, expressed in endotoxin units (EU/ml), of all assays was 0.041 EU/ml.

Laboratory analysis was carried out at the Institute of Risk Assessment Studies, Utrecht University, The Netherlands.

### Data analysis

Pearson's chi-squared test was used to compare prevalence of environment-related and living habit factors between groups. Concentrations of allergens and endotoxin were expressed per gram dust ('level', in ng/g dust and EU/g dust, respectively) and per square meter ('load', in ng/$m^2$ and EU/$m^2$, respectively). Because these allergen and endotoxin data had logarithmic distributions, all statistical analyses of these variables were done on log-transformed data.

The relations between the levels or loads of allergens and endotoxin and various housing or occupant characteristics were examined in a univariate analysis, using ANOVA, and Pearson's correlation coefficient was used for calculating the bivariate correlation coefficient (*r*). Multivariate linear regression models were then applied separately for Der p1, Der f1, Fel d1, Can f1 and endotoxin, to identify independent explanatory variables for the variance after accounting for the effects of other relevant factors. Variables which were significant at $P < 0.1$ in the univariate analysis (either mattress or floor, either level or load), those exhibiting a large effect in the preliminary analysis or those previously described as important in influencing the concentrations of allergens or endotoxin were included in the models. Only the results of the multivariate regression analysis are presented.

The adjusted means ratios (AMR) were calculated from the coefficient (β) of the linear regression model as exp(β). All analyses were performed using the statistical package SPSS (10).

## Results

### General characteristics of the domestic environment and living habits in cities, villages and refugee camps

Out of 375 children, 132 had been selected for dust sampling in their homes, of whom 120 families agreed to participate, but we were able to collect samples from only 110 houses. Four families in cities and two in villages had moved at the time of the visit and could not be reached, and four families in the refugee camps had given inaccurate addresses and we were unable to find them.

The average weight of dust samples was 1.49 g (range 0.12–5.61 g). The amount collected from mattresses and floors (mean in g/$m^2$ with standard deviation, SD) was significantly ($P < 0.05$) lower in cities [0.29 (SD 0.20) and 0.62 (SD 0.44), respectively] than in villages [0.59 (SD 0.31) and 0.98 (SD 0.45), respectively], or camps [0.62 (SD 0.36 and 0.99 (SD 0.75), respectively).

Refugee camps were characterized by having relatively small houses (only six houses contained more than five rooms) and high building density (nine houses out of 10 were less than 3 m apart) (see Fig. 1A). As expected, people in villages more frequently kept farm animals close to home, sometimes less than 3 m, and sometimes within the house itself (see Fig. 1B), compared to cities or camps (although, even in these locations, there were sometimes animals in close vicinity). The number of persons per room did not differ significantly between locations. However, room space (not measured) was considerably smaller in refugee camps than elsewhere, leading to a higher crowdedness in refugee camps. Three-fourths of the houses in refugee camps were characterized as damp and contained visible molds (see Fig. 1C), while this was less prevalent in cities and villages. Many other characteristics were also assessed but no particular differences were found between locations.

### Mite and pet allergens and endotoxin concentrations

The correlation between levels (concentrations per weight of collected dust) and loads (concentrations per square

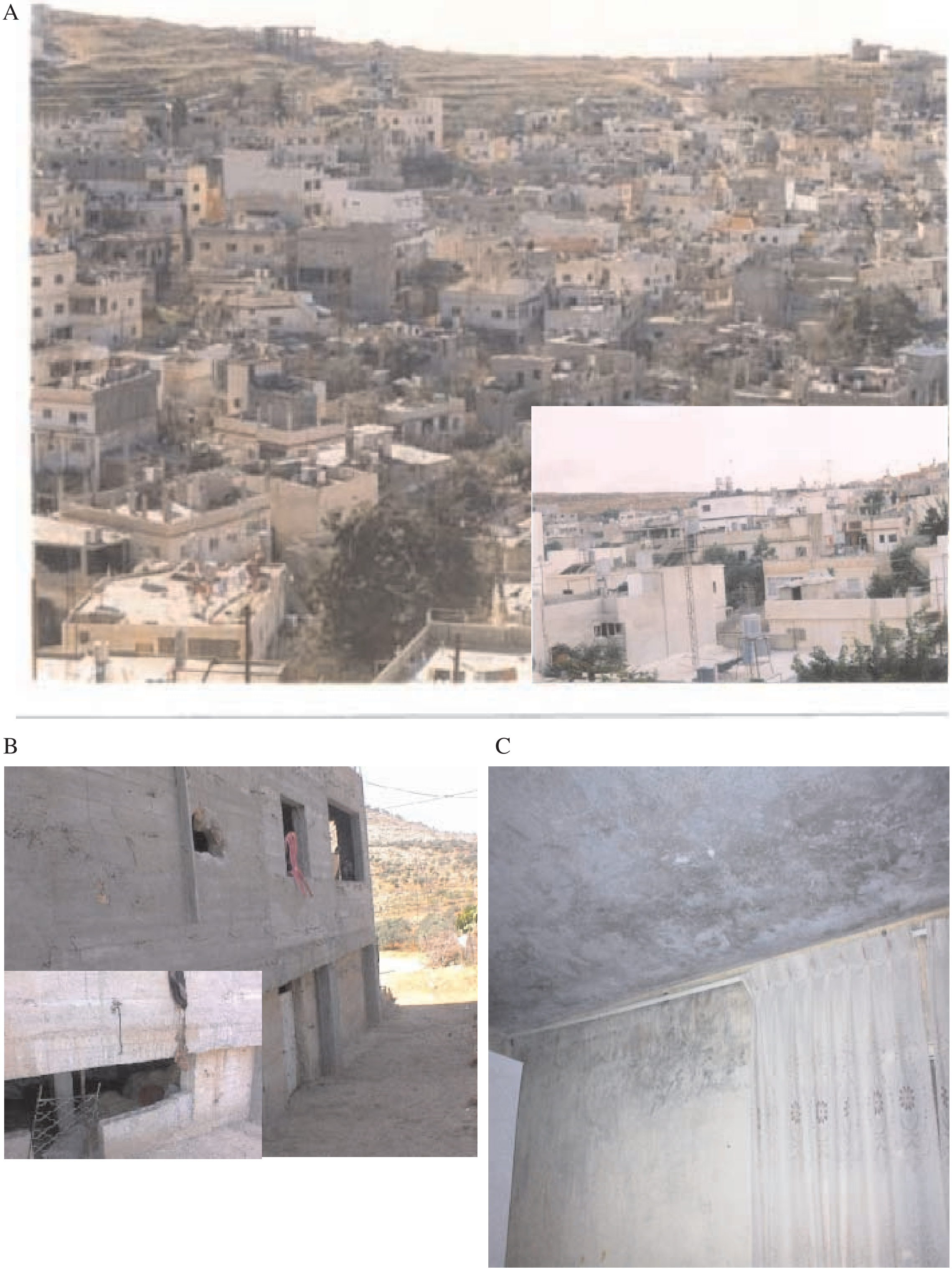
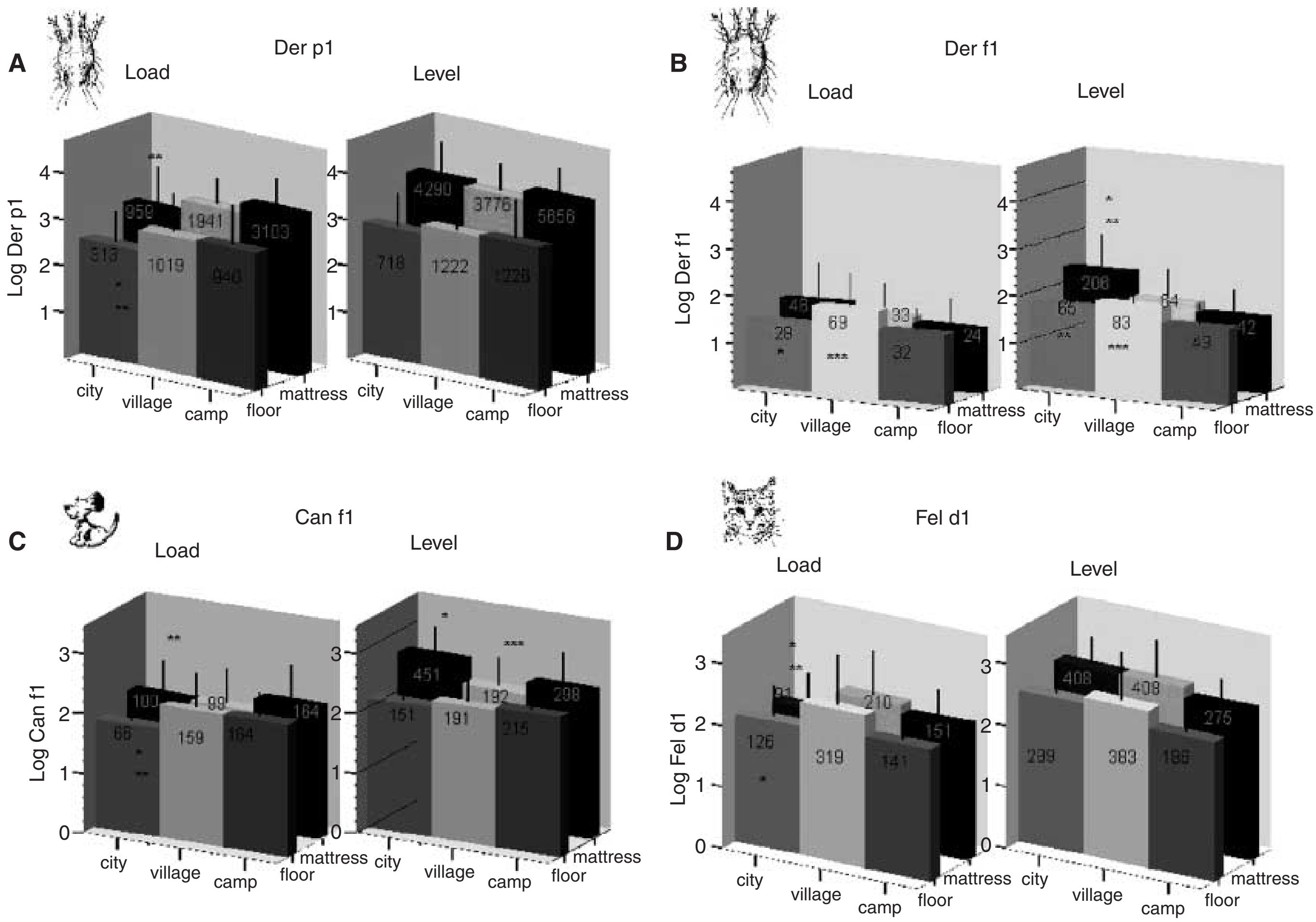



*Figure 1.* (A) View of Jalazon refugee camp in Palestine illustrating building density. (B) Animals kept close/underneath the houses in villages. (C) Visible molds in a house from a refugee camp.

meter) was high (allergen Pearson correlation coefficient, $r > 0.66$ and for endotoxin $r > 0.88$). The correlations between allergen concentrations and endotoxin (expressed either as levels or loads) in mattress dust and those in floor dust were modest (Pearson $r \leq 0.40$). No correlations were found when comparing the endotoxin loads and levels with mite and pet allergen loads and levels in mattress and floor dust (Pearson $r < 0.03$).

In Fig. 2A,B, it appears that concentrations of Der p1 were more than one order of magnitude higher than those of Der f1. In mattress dust, the mean load of Der p1 was lowest in cities but three times higher in camps, although mean levels did not differ significantly between locations of residence. However, the trend was opposite for Der f1 in mattress dust. In floor dust, the lowest load of Der p1 was again found in cities, whereas villages had the highest mean load and level of Der f1.

Figure 2C,D shows that pet allergens levels were generally higher on mattresses than on floors, but this was not so for loads. The contamination by cat allergens appeared to be lowest in cities and highest in villages, but this was only the case for Fel d1 concentrations when



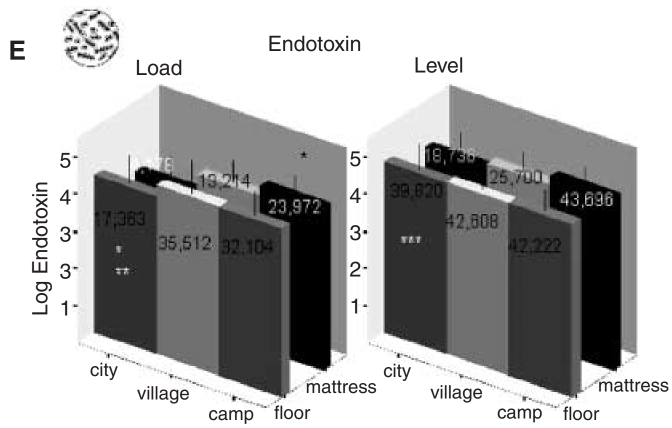




*Figure 2*. Allergen loads (ng/m$^2$) and levels (ng/g dust) of (A) *Dermatophagoides pteronyssinus* (Der p1), (B) *Dermatophagoides farinae* (Der f1), (C) dog (Can f1), and (D) cat (Fel d1), and (E) endotoxin loads (EU/m$^2$) and levels (EU/g dust) in mattresses and living room floors in houses of the Ramallah district. Error bars indicate +1GSD. Data on bars are geometric means. *Post hoc* test significance $P < 0.05$: *city to village comparison, **city to refugee camp comparison, ***village to refugee camp comparison.

expressed as loads. Levels of Fel d1 did not differ between locations. The pattern of contamination by dog allergens was not very consistent, with cities exhibiting both the lowest Can f1 load in floor dust, and the highest Can f1 level in mattress dust.

Figure 2E shows that on mattresses, concentrations of endotoxin were lowest in cities, intermediate in villages and highest in refugee camps. Differences were less marked in floor dust, but endotoxin load was lower in the floor dust from cities.

### Domestic environment and living habits association with allergens and endotoxin

Table 1 shows that contamination by mite allergens and location of residence remained significantly associated in the multivariate regression, with refugee camps exhibiting the highest Der p1 but also the lowest Der f1 concentrations. Living on the ground floor was associated with higher Der p1 contamination on mattresses, but dwelling storey and type of floor cover were associated with both loads and levels of Der f1 on floors.

Table 2 shows that location of residence remained a significant (but complex) predictor of Fel d1 levels. The presence of a cat indoors was the major factor predicting concentrations of Fel d1 in mattress and floor dust, but dog ownership was not associated with Can f1 concentrations. Living in a farm also influenced Fel d1 levels, but this factor was a positive predictor for mattress levels and a negative predictor of floor dust levels. However, location of the house was the only factor associated with dog allergens loads.

Table 1. AMR of mite allergens (Der p1 and Der f1) concentrations in mattress and floor dust in relation to potential influencing factors in houses from Ramallah district

| | | Der p1 | | | | Der f1 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mattress AMR (95% CI) | | Floor AMR (95% CI) | | Mattress AMR (95% CI) | | Floor AMR (95% CI) | |
| | *n* | ng/g dust | ng/m$^2$ | ng/g dust | ng/m$^2$ | ng/g dust | ng/m$^2$ | ng/g dust | ng/m$^2$ |
| Model intercept | | **38** (21.7–66.7) | **29.7** (16.3–53.8) | **22.3** (10.1–49) | **19.9** (9.33–42.3) | **5.05** (2.80–9.13) | **4.02** (2.18–7.41) | **3.69** (2.28–5.97) | 3.31 (2.04–5.35) |
| Place of residence | | | | | | | | | |
| Village | 38 | 0.92 (0.68–1.25) | 0.84 (0.61–1.17) | 0.97 (0.64–1.46) | 0.93 (0.63–1.38) | 1.26 (0.91–1.75) | 1.13 (0.81–1.58) | **1.44** (1.12–1.85) | 1.39 (1.08–1.79) |
| City | 36 | 0.91 (0.66–1.26) | **0.64** (0.45–0.90) | 0.78 (0.51–1.21) | **0.58** (0.38–0.87) | **1.80** (1.28–2.53) | 1.23 (0.87–1.75) | 1.26 (0.97–1.64) | 0.93 (0.72–1.21) |
| Refugee camps | 36 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | | 1.00 | 1.00 |
| Dwelling storey | | | | | | | | | |
| Separate house, one floor | 48 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Ground floor | 30 | **1.36** (1.01–1.85) | **1.45** (1.05–2.01) | 1.08 (0.72–1.62) | 1.14 (0.78–1.68) | 1.15 (0.83–1.58) | 1.23 (0.88–1.71) | **1.33** (1.04–1.70) | 1.40 (1.10–1.79) |
| First floor | 24 | 0.85 (0.61–1.18) | 0.88 (0.62–1.25) | 0.97 (0.62–1.52) | 1.01 (0.66–1.56) | 1.23 (0.87–1.74) | 1.33 (0.93–1.92) | **1.48** (1.12–1.95) | 1.55 (1.18–2.05) |
| More than two floors | 8 | 1.28 (0.76–2.15) | 1.36 (0.78–2.35) | 1.09 (0.55–2.17) | 1.26 (0.65–2.43) | 1.23 (0.71–2.12) | 1.30 (0.74–2.29) | 0.80 (0.53–1.22) | 0.93 (0.61–1.41) |
| Living in a farm | | | | | | | | | |
| Yes | 30 | 0.79 (0.59–1.07) | 0.93 (0.67–1.28) | 0.91 (0.61–1.36) | 1.04 (0.71–1.54) | 0.90 (0.65–1.23) | 1.03 (0.74–1.44) | 0.81 (0.63–1.03) | 0.93 (0.72–1.18) |
| No | 80 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Fungus on walls or ceiling | | | | | | | | | |
| Yes | 62 | 1.23 (0.89–1.69) | 1.21 (0.86–1.71) | 1.17 (0.76–1.79) | 1.17 (0.77–1.76) | 0.95 (0.67–1.33) | 0.92 (0.65–1.31) | 1.20 (0.92–1.55) | 1.20 (0.92–1.56) |
| No | 48 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Windows | | | | | | | | | |
| Single glass | 93 | 1.04 (0.71–1.53) | 1.02 (0.67–1.54) | 1.21 (0.72–2.03) | 1.22 (0.74–2.01) | 0.81 (0.54–1.22) | 0.80 (0.52–1.22) | 1.13 (0.83–1.55) | 1.14 (0.83–1.57) |
| Double glass | 12 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Crowding | | | | | | | | | |
| Less than two persons/room | 20 | 0.95 (0.69–1.33) | 0.92 (0.65–1.30) | 0.87 (0.56–1.34) | 0.80 (0.53–1.21) | 1.12 (0.79–1.58) | 1.09 (0.76–1.56) | 1.20 (0.92–1.56) | 1.10 (0.84–1.43) |
| Two to four persons/room | 69 | 1.11 (0.73–1.69) | 1.19 (0.77–1.86) | 1.21 (0.70–2.09) | 1.25 (0.74–2.12) | 0.98 (0.63–1.51) | 1.05 (0.66–1.65) | 1.25 (0.90–1.75) | 1.29 (0.93–1.81) |
| >Four persons/room | 21 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Having mattress cover | | | | | | | | | |
| Yes | 62 | 0.97 (0.74–1.28) | 0.89 (0.67–1.19) | – | | 1.16 (0.87-1.55) | 1.04 (0.77-1.40) | – | |
| No | 48 | 1.00 | 1.00 | – | | 1.00 | 1.00 | – | |
| Type of floor cover | | | | | | | | | |
| Rock floor | 36 | – | – | 0.83 (0.51-1.35) | 0.74 (0.46-1.18) | – | – | 0.74 (0.55-1.00) | **0.66** (0.49-0.89) |
| Carpet | 54 | – | – | 0.85 (0.52-1.40) | 0.93 (0.58-1.51) | – | – | 0.99 (0.73-1.35) | 1.09 (0.80-1.48) |
| Plastic rugs or PVC | 24 | – | – | 1.00 | 1.00 | – | – | 1.00 | 1.00 |

Variables in the models are those showing a *P*-value <0.1 by ANOVA either with levels or with loads. Significant ratios are given in bold.

Table 2. AMR of cat (Fel d1) and dog allergens (Can f1) concentrations in mattress and floor dust in relation to potential influencing factors in houses from Ramallah district

| | | Fel d1 | | | | Can f1 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mattress AMR (95% CI) | | Floor AMR (95% CI) | | Mattress AMR (95% CI) | | Floor AMR (95% CI) | |
| | *n* | ng/g dust | ng/m$^2$ | ng/g dust | ng/m$^2$ | ng/g dust | ng/m$^2$ | ng/g dust | ng/ m$^2$ |
| Model intercept | | **9.39** (6.26–14.1) | **7.15** (4.47–11.4) | **12.6** (7.74–20.4) | **12.0** (7.28–19.7) | **8.61** (5.39–13.8) | **6.37** (3.70–11.0) | **8.89** (5.51–14.3) | 8.27 (5.13–13.3) |
| Place of residence | | | | | | | | | |
| Village | 38 | 1.07 (0.85–1.35) | 0.95 (0.73–1.24) | **1.34** (1.01–1.77) | 1.27 (0.96–1.69) | 0.90 (0.69–1.17) | 0.81 (0.60–1.09) | 0.99 (0.76–1.30) | 0.95 (0.73–1.24) |
| City | 36 | 1.15 (0.92–1.45) | **0.76** (0.58–0.99) | 1.13 (0.86–1.49) | 0.85 (0.64–1.12) | 1.24 (0.96–1.61) | 0.83 (0.61–1.12) | 0.88 (0.68–1.15) | **0.66** (0.51–0.86) |
| Refugee camps | 36 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Distance between houses | | | | | | | | | |
| <3 m | 77 | 1.09 (0.88–1.34) | 1.03 (0.81–1.31) | 1.07 (0.83–1.37) | 1.00 (0.77–1.28) | 1.08 (0.85–1.36) | 1.01 (0.77–1.33) | 1.19 (0.94–1.51) | 1.10 (0.87–1.40) |
| >3 m | 33 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Dwelling storey | | | | | | | | | |
| Separate house, one floor | 48 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Ground floor | 30 | 0.99 (0.79–1.24) | 1.07 (0.82–1.38) | **0.74** (0.57–0.97) | 0.79 (0.60–1.04) | 1.19 (0.92–1.55) | 1.30 (0.97–1.76) | 0.88 (0.68–1.15) | 0.96 (0.74–1.24) |
| First floor | 24 | 1.10 (0.86–1.39) | 1.14 (0.87–1.50) | 0.81 (0.61–1.08) | 0.90 (0.67–1.20) | 0.93 (0.71–1.21) | 0.95 (0.70–1.30) | 0.87 (0.67–1.14) | 0.95 (0.73–1.25) |
| Greater than two floors | 8 | 0.84 (0.58–1.21) | 0.89 (0.58–1.37) | **0.55** (0.35–0.85) | 0.65 (0.41–1.02) | 0.92 (0.60–1.40) | 0.99 (0.61–1.61) | 0.99 (0.65–1.52) | 1.18 (0.77–1.81) |
| Crowding | | | | | | | | | |
| Less than two persons/room | 20 | 1.11 (0.88–1.41) | 1.07 (0.82–1.41) | 1.08 (0.81–1.43) | 0.99 (0.74–1.33) | 1.24 (0.94–1.63) | 1.24 (0.90–1.70) | 0.96 (0.73–1.27) | 0.91 (0.69–1.20) |
| Two to four persons/room | 69 | 1.26 (0.93–1.71) | 1.34 (0.94–1.90) | 1.21 (0.84–1.75) | 1.24 (0.86–1.80) | 1.20 (0.86–1.69) | 1.29 (0.87–1.92) | 1.19 (0.84–1.68) | 1.22 (0.87–1.73) |
| >Four persons/room | 21 | 1.00 | | 1.00 | | 1.00 | 1.00 | 1.00 | 1.00 |
| Windows | | | | | | | | | |
| Single glass | 93 | 0.95 (0.72–1.25) | 0.95 (0.69–1.31) | 0.84 (0.61–1.18) | 0.82 (0.59–1.16) | 1.12 (0.82–1.54) | 1.14 (0.79–1.64) | 1.10 (0.80–1.52) | 1.09 (0.79–1.50) |
| Double glazing | 12 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | |
| Living in a farm | | | | | | | | | |
| Yes | 30 | 1.16 (0.94–1.44) | **1.38** (1.08–1.77) | **0.69** (0.53–0.89) | 0.79 (0.61–1.03) | 0.81 (0.64–1.04) | 0.95 (0.72–1.26) | 0.94 (0.74–1.21) | 1.08 (0.84–1.38) |
| No | 80 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Fungus on walls or ceiling | | | | | | | | | |
| Yes | 62 | 0.99 (0.78–1.24) | 0.98 (0.75–1.28) | 0.96 (0.73–1.27) | 0.93 (0.70–1.23) | 0.88 (0.68–1.14) | 0.87 (0.64–1.18) | 1.02 (0.78–1.33) | 0.98 (0.75–1.28) |
| No | 48 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Presence of cat indoors | | | | | | | | | |
| Yes | 11 | **2.13** (1.57–2.89) | **2.46** (1.73–3.50) | **2.22** (1.54–3.19) | **2.42** (1.66–3.50) | – | – | – | – |
| No | 99 | 1.00 | 1.00 | 1.00 | 1.00 | – | – | – | – |
| Presence of dog indoors | | | | | | | | | |
| Yes | 11 | – | – | – | – | 1.09 (0.66–1.77) | 1.33 (0.75–2.33) | 0.71 (0.43–1.16) | 0.81 (0.49–1.34) |
| No | 99 | – | – | – | – | 1.00 | 1.00 | 1.00 | |

Variables in the models are those showing a *P*-value <0.1 by ANOVA either with levels or with loads. Significant ratios are given in bold.

For endotoxin (Table 3), the effect of place of residence was still apparent. In addition, living close to farm animals was a predictor of higher endotoxin loads on mattresses and floors. No other factors appeared to be significant predictors. The presence of damp/mold or a cat appeared to be associated with somewhat lower endotoxin concentrations in the dust but this was not statistically significant.

## Discussion

This study is novel in its findings, not only for Palestine and the Middle East, but also because not many studies are available where four allergens and endotoxin have been measured in more than one type of housing environment. A few studies investigated the association between housing characteristics and allergens or endotoxin levels in urban and rural settings (11), but no studies have been published that have investigated these levels in refugee camps. We were able to show, for the first time, that concentrations of mite and pet allergens in dust collected from mattresses and living room floor in Palestinian homes differ between cities, villages and refugee camps. In addition, domestic dust endotoxin levels also differed among the three localities.

Table 3. AMR of endotoxin concentrations in mattress and floor in relation to potential influencing factors in houses from Ramallah district

| | *n* | Mattress endotoxin | | Floor endotoxin | |
|---|---|---|---|---|---|
| | | EU/g | EU/m$^2$ | EU/g | EU/m$^2$ |
| Model intercept | | **53.7** (30.1–96) | 97.7 (60.2–158) | **61.9** (35.4–107) | **55** (29–106) |
| Place of residence | | | | | |
| Village | 38 | 1.19 (0.84–1.69) | **0.73** (0.54–0.98) | 1.18 (0.83–1.68) | 1.13 (0.75–1.71) |
| City | 36 | 1.07 (0.74–1.55) | **0.50** (0.37–0.69) | 1.15 (0.81–1.63) | 0.86 (0.57–1.29) |
| Refugee camps | 36 | 1.00 | 1.00 | 1.00 | 1.00 |
| Distance between houses | | | | | |
| <3 m | 77 | **1.42** (1.03–1.94) | 1.15 (0.88–1.49) | **1.43** (1.04–1.95) | 1.31 (0.91–1.89) |
| >3 m | 33 | 1.00 | | 1.00 | 1.00 |
| Dwelling storey | | | | | |
| Separate house | 48 | 1.00 | 1.00 | 1.00 | 1.00 |
| Ground floor | 30 | 0.77 (0.55–1.09) | 0.89 (0.67–1.19) | 0.78 (0.56–1.10) | 0.85 (0.58–1.26) |
| First floor | 24 | 0.74 (0.51–1.07) | 0.77 (0.57–1.05) | 0.77 (0.53–1.10) | 0.84 (0.55–1.28) |
| Greater than two floors | 8 | 0.93 (0.53–1.65) | 1.60 (1.00–2.57) | 0.95 (0.54–1.67) | 1.11 (0.57–2.14) |
| Windows | | | | | |
| Single glass | 93 | 1.50 (0.98–2.29) | 0.80 (0.57–1.14) | 1.44 (0.95–2.20) | 1.43 (0.87–2.34) |
| Double glazing | 12 | 1.00 | 1.00 | 1.00 | |
| Living in a farm | | | | | |
| Yes | 30 | 1.04 (0.75–1.44) | **1.39** (1.06–1.82) | 1.00 (0.72–1.37) | 1.14 (0.78–1.66) |
| No | 80 | 1.00 | 1.00 | 1.00 | |
| Fungus on walls or ceiling | | | | | |
| Yes | 62 | 0.80 (0.57–1.14) | 0.97 (0.72–1.29) | 0.81 (0.57–1.14) | 0.77 (0.52–1.15) |
| No | 48 | 1.00 | 1.00 | 1.00 | |
| Having cat indoors | | | | | |
| Yes | 11 | 0.85 (0.53–1.35) | 0.74 (0.50–1.09) | 0.83 (0.52–1.32) | 0.91 (0.53–1.56) |
| No | 99 | 1.00 | 1.00 | 1.00 | |
| Synthetic quilts | | | | | |
| Yes | 11 | 0.91 (0.61–1.36) | 0.89 (0.64–1.24) | – | – |
| No | 99 | 1.00 | 1.00 | – | – |
| Having mattress cover | | | | | |
| Yes | 62 | 1.29 (0.96–1.73) | 0.85 (0.66–1.09) | – | – |
| No | 48 | 1.00 | 1.00 | – | – |

Variables in the models are those showing a *P*-value < 0.1 by ANOVA either with levels or with loads. Significant ratios are given in bold.

## Determinants of mite allergen concentrations

In our study, measuring two types of mite allergens in domestic dust showed that Der p1 was the dominant type in Ramallah district. Geometric mean levels measured in our study (4.48 μg/g mattress dust and 1.23 μg/g floor dust) are similar to or somewhat higher than those reported in some Western European countries such as the Netherlands (2.37 μg/g) (12) and Spain (0.68 μg/g) (13), but they are much lower than those reported in the UK (16.1 μg/g) (14). Concentrations of Der f1 have been measured less frequently. In Germany and Denmark, levels of Der f1 in mattress dust were higher than those of Der p1 (15), but this was not so in our study (geometric mean, GM < 0.08 μg/g).

Many studies have investigated the role of various home characteristics and cleaning practices on mite concentrations (16), but these are still considered to be poor predictors for mite allergen levels (17). In our study, damp houses (approximately 55%), particularly in refugee camps, had the highest Der p1 levels. Sampling was conducted in spring when relative humidity and temperatures in the Ramallah district, are moderate, i.e. optimum conditions for mite proliferation, especially Der p1 (18). Comparing cities, villages and refugee camps, damp city houses showed significantly high Der f1 levels (200–400 ng/g dust) compared to houses that are not damped, and the highest levels were found in mattress dust (data not shown). Several studies showed that houses with observed or reported signs of dampness have a tendency to have higher Der p1 concentration in dust (19).

Half of the families in our study, and up to 60% of village houses, did not use mattress covers for their children. However, we could not show a clear importance of the presence or type of mattress covers on mite levels. Many intervention studies have recommended the use of mattress covers, particularly encasing mattresses with impermeable covers for allergic patients, frequent laundering of bedding and using effective measures to control fungal growth to decrease exposure to indoor allergens

(8, 20). Families in Palestinian villages usually expose their mattresses almost daily to the sun outside for several hours. We speculate that this method may be an effective control measure for mites, which might explain the lack of difference in levels between covered and uncovered mattresses. In other words, exposing the mattress daily to the sun may be as effective for preventing high mite contamination as protecting the mattress with bed sheets, which might explain the similarity of mite concentrations found in this study to those of Europe.

### Determinants of cat and dog allergen concentrations

In this study, concentration of Fel d1 was the highest in villages, and Can f1 was the highest in mattresses from cities and floor dust from refugee camps. The measured Fel d1 geometric mean levels ($< 0.40$ μg/g) are similar to those of some Western European countries such as Spain (0.48 μg/g) (13), but lower than those reported in the UK (31.7 μg/ g) (21). The Can f1 levels measured in this study ($< 0.30$ μg/g) are also similar to those reported in the Netherlands (0.19 μg/$m^2$) (9), but much lower than the Estonian levels (0.73 μg/g) (22).

In our study, the presence of a cat in the house was the strongest determinant of high allergen Fel d1 concentrations, but this was not the case for the levels of Can f1, which were not associated with the presence of dogs in the home. Ghanaian homes with or without cats showed lower levels of cat allergen (GM 0.11 μg/g dust) compared with homes in the UK (GM 31.7 and 0.43 μg/g dust, respectively) (21). In the current study, pet ownership was reported by only a few families (11 had cats and six had dogs), which is very low compared to other Western countries (48% in Australia and 7.8% in Spain) (23–25). Due to its particulate size ($< 5$ μm diameter), cat allergens might be present in homes without a cat, in schools and on children's clothes, which is probably the main source of cat allergens in the indoor environment when cats are not present. This is in contrast to dog allergens (24, 26, 27).

### Determinants of endotoxin concentrations

This study shows that mattress endotoxin levels (25.7 EU/ mg mattress dust and 49 EU/mg floor dust) were higher than those reported in some studies in Western European countries such as Belgium (13.2 EU/mg) (1) and The Netherlands (17.3 EU/mg floor dust). Higher levels were seen in Boston, USA (43.5 EU/mg) (28). In refugee camps, mean endotoxin levels in mattress dust were similar to those seen in farms in Switzerland, Austria and Germany (37.8 EU/mg), but they were lower for mattresses in cities and villages compared to those from nonfarming houses in these countries (22.8 EU/mg) (29).

Housing characteristics, such as distance between houses, distance from animals or presence of fungi on walls or ceilings were not associated with endotoxin levels, in contrast to other studies (30). However, endotoxin levels appeared to be associated with certain living habits such as use of mattress covers and method of cleaning floors. We found higher endotoxin levels in mattresses where no sheet cover was used, and on floors where dusting and/or brushing was used. This supports several published studies that showed that vacuuming is the best method to decrease house dust mites and endotoxin levels (31). Similar findings were seen in Belgium and Germany (1, 32). Our study suggests that low socioeconomic status (i.e. smaller houses, crowded houses and dampness) was an important predictor for endotoxin levels in Palestine. Similar findings in Denver, USA, showed that houses of highly educated families and neighboring homes had lower endotoxin levels than homes of low-income families (33).

## Conclusion

Der p1 antigens are present in high concentrations in Palestinian house dust, and pet allergens concentrations could be important in the epidemiology of allergies and asthma in children. This is also applied for the exposure to bacterial endotoxin in domestic dust. We could not find clear-cut evidence that any of the investigated indoor environmental factors or living habits strongly determine these allergens and endotoxin concentrations. However, the place of residence was a strong determinant for these allergens and endotoxin, but the characteristics presented in these environments varied in their association with these concentrations. Other possible explanations for differences between cities, villages and refugee camps could also be related to differences in socioeconomic factors like poverty.

When comparing our results to other studies, we cannot exclude the differences in dust composition, the climatological variations and differences in the indoor environment and lifestyle factors, as well as variations in the used analytical procedures. Moreover, other housing characteristics, which we did not investigate, might also be correlated to allergen and endotoxin levels and might, thus, confound/modify such associations. Therefore, this study finding might suggest that the differences in '12-month wheezing' seen in the baseline study (4) could be related to differences in the measured allergen or endotoxin concentrations in the indoor dust.

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