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Tokelau: a unique low allergen environment at sea level

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Summary

Background Previous studies have shown that children in Tokelau have a lower prevalence of asthma and atopy compared to Tokelauan children resident in New Zealand. We hypothesized that the low asthma and atopy prevalence in Tokelau may be associated with low indoor allergen levels.

Methods Dust was collected from bedding and floors of 76 homes and four public buildings in Tokelau and from the homes of 30 Tokelauan families in Wellington, New Zealand. Dust samples were analysed for Der p 1, Der f 1, Can f 1, Fel d 1, Bla g 2 and Blo t 5 by ELISA, and for endotoxin by a kinetic amoebocyte lysate assay.

Results Der p 1 levels were over 1000-fold lower in Tokelau compared to New Zealand, geometric mean levels were 0.04 and 47.0 μg/g in beds and 0.04 and 44.7 μg/g on floors, respectively. Can f 1 and Fel d 1 levels were also significantly lower in Tokelau. Bed endotoxin levels were significantly higher in Tokelau, geometric mean: 26 736 EU (endotoxin units)/g, compared to 5181 EU/g in New Zealand. Floor endotoxin levels were similar between the two countries.

Conclusion The very low indoor allergen levels in homes in Tokelau compared to much higher levels in New Zealand homes provides a logical explanation for the lower prevalence of asthma and atopy in Tokelau, compared to New Zealand.

Keywords cat, cockroach, dog, endotoxin, house dust mites, New Zealand, Tokelau

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Introduction

Longitudinal studies have shown that sensitization to indoor allergens is a risk factor for development of asthma in childhood [1, 2]. House dust mite (HDM) allergens are present from birth at very high levels in infant bedding in New Zealand [3] and might, in part, explain the high rates of asthma in New Zealand [4].

Following hurricane damage to the Tokelau atolls in 1966 half of the population resettled in New Zealand. A programme of studies was established to measure the health effects of this migration. In the 1970s it was noted that asthma was rare among Tokelauans living in Tokelau compared to Tokelauans living in New Zealand [5]. Subsequently, Waite et al. [6] studied asthma prevalence in Tokelauan children in Tokelau and New Zealand. They classified 11.0% of 706 children in Tokelau as asthmatics, compared with 25.3% of 1160 Tokelauan children in New Zealand. In that study, asthma was defined as either probable (history of asthma or current physical signs of asthma) or definite (history of asthma and current physical signs of asthma). Importantly, of the children studied in New Zealand, there was no difference in asthma prevalence between those children born in New Zealand or those born in Tokelau.

In the 1980s, we found that atopy was more common among 5–9-year old Tokelauan children living in New Zealand (30%) than 5–9-year old Tokelauan children in Tokelau (5%) [7]. Among the older children (10–15 years) asthma symptoms were more prevalent in New Zealand (8% vs. 3%) and their asthma was more severe, while atopy was threefold higher in New Zealand (33%) than Tokelau (9%). In that study, asthma symptoms were defined as 'ever wheezing' or 'wheeze in the last 12 months'.

There is reason to believe that Tokelau might be a low indoor allergen environment and that this could explain the lower prevalence of asthma and atopy in children resident in there, compared to Tokelauan children resident in New Zealand. Tokelau consists of three small isolated atolls situated 1000 km South of the Equator in the South Pacific Ocean. The coral atolls sustain little flora and fauna, in particular with no common grasses and no domestic cats or dogs (these were eradicated in the 1950s). Tokelauan homes traditionally consist of one or two rooms that are used for living, cooking and sleeping. To aid with ventilation and temperature control, windows are usually not glassed and the floors are bare (no carpets) or covered with locally woven or imported synthetic mats that are often also used to sleep on. Tokelauans tend to keep livestock, predominantly chickens and pigs, close to their dwelling.

In this study, we have measured indoor allergens and endotoxin levels from bedding and floors in homes in Tokelau

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and compared them to levels in the homes of Tokelauans resident in New Zealand.

Materials and methods

In 2000, one of the authors (G.P.) visited the three atolls of Tokelau and collected dust samples from 76 dwellings and four public buildings (one school, guesthouse, hospital and hotel). The same procedure was carried out in homes of 30 Tokelauan families resident in Wellington, New Zealand. Dust samples were collected from the centre of the living room floor and from the top of one bedding surface by vacuuming 1 m^2 for 1 min from carpeted floors and bedding surfaces and for 2 min from uncarpeted floors with a Hitachi (Tokyo, Japan) CV-2500 vacuum cleaner (1100 W) with nylon mesh sleeve attached to the vacuum head. The type of flooring and bedding surfaces were recorded.

All collected dust samples were stored at -20° before sifting through a 425 μm steel mesh sieve. Aliquots of fine sifted dust was extracted (100 mg in 1.0 mL of phosphate-buffered saline containing 0.05% Tween-20) for 30 min at room temperature, centrifuged for 10 min at 3000 ***g*** and supernatants stored at -20° for allergen determinations. If sufficient fine dust was available, 200 mg was extracted with 5.0 mL of endotoxin-free water containing 0.05% Tween-20 for 30 min at room temperature, centrifuged for 15 min at 1000 ***g*** and supernatants stored at -20° for endotoxin activity determination.

The indoor allergens, Der p 1, Der f 1, Can f 1, Fel d 1, Bla g 2 and Blo t 5 were determined by double monoclonal and monoclonal/polyclonal antibody ELISA by standard protocols with the use of commercial kit sets (Indoor Biotechnologies, Cardiff, UK). Endotoxin activity was determined by a kinetic procedure with a commercial amoebocyte lysate kit set (BioWhittaker, Walkersville, MD, USA).

Due to non-Gaussian data distribution, allergen and endotoxin levels were log transformed. Dust samples with undetectable allergen levels were assigned a value of 0.01 μg/g, the lower level of detection. Indoor allergen results are expressed as μg/g dust and endotoxin activity as endotoxin units (EU)/g dust. Statistical analysis was by two-tailed non-paired Student's *t*-test with statistical significance set at the $P > 0.05$ level. The Wellington Ethics Committee approved the study.

Table 1. Proportion of dust samples that contain detectable indoor allergens

Allergen and location	Tokelau	New Zealand
Floor Der p 1	26/80	30/30
Floor Der f 1	26/80	4/30
Floor Can f 1	45/80	30/30
Floor Fel d 1	57/80	30/30
Floor Bla g 2	1/80	10/30
Floor Blo t 5	2/80	1/30
Bedding Der p 1	21/77	30/30
Bedding Der f 1	53/77	19/30
Bedding Can f 1	32/77	30/30
Bedding Fel d 1	59/77	29/30
Bedding Bla g 2	0/77	11/30
Bedding Blo t 5	0/77	2/30

Table 2. Bedding allergens and endotoxin levels in Tokelau and New Zealand

	Tokelau	New Zealand
Der p 1 (μg/g)	0.04** (0.02–0.07)	47.0 (32.5–67.9)
Der f 1 (μg/g)	0.12 (0.08–0.19)	0.15 (0.06–0.35)
Can f 1 (μg/g)	0.03* (0.02–0.05)	0.47 (0.34–0.65)
Fel d 1 (μg/g)	0.33* (0.20–0.57)	1.25 (0.69–2.24)
Bla g 2 (μg/g)	ND	0.04 (0.02–0.07)
Blo t 5 (μg/g)	ND	0.02 (0.01–0.03)
Endotoxin (EU/g)	26 736** (21 380–33 497)	5181 (3148–8531)

Results are geometric means with 95% confidence intervals in brackets.
ND, none detected in any dust sample; EU, endotoxin units.
*$P < 0.05$. **$P < 0.001$.

Table 3. Flooring allergens and endotoxin levels in Tokelau and New Zealand

	Tokelau	New Zealand
Der p 1 (μg/g)	0.04** (0.03–0.07)	44.7 (26.6–75.3)
Der f 1 (μg/g)	0.03* (0.02–0.04)	0.01 (0.005–0.02)
Can f 1 (μg/g)	0.06** (0.04–0.08)	0.62 (0.10–0.95)
Fel d 1 (μg/g)	0.28* (0.16–0.48)	0.86 (0.50–1.50)
Bla g 2 (μg/g)	0.01* (0.01–0.01)	0.03 (0.01–0.05)
Blo t 5 (μg/g)	0.01 (0.01–0.01)	0.01 (0.005–0.02)
Endotoxin (EU/g)	14 104 (11 220–17 742)	21 754 (12 942–36 559)

Results are geometric means with 95% confidence intervals in brackets.
EU, endotoxin units.
*$P < 0.05$. **$P < 0.001$.

Results

Seventy-seven bed dust samples and 80 floor dust samples from Tokelau were analysed for the six indoor allergens and compared with 30 bed dust and 30 floor dust samples from the New Zealand homes. There was sufficient dust for endotoxin analysis for 69 bed and 56 floor samples from Tokelau, and 29 bed and 29 floor dust samples from New Zealand.

Table 1 shows the number of dust samples in which allergens were detected. All dust samples from Tokelau and New Zealand had detectable endotoxin levels. Tables 2 and 3 show the geometric mean allergen and endotoxin levels (with 95% confidence intervals (CI)) from bedding and floor dust samples in Tokelau and New Zealand. Der p 1, Can f 1, Fel d 1 and Bla g 2 levels were significantly higher in the New Zealand bedding and floor dust samples, compared to Tokelau. Indeed, Der p 1 levels were more than 1000-fold lower in Tokelau where less than one third of dust samples had detectable levels, compared to all of the New Zealand dust samples. Additionally, when analysed as μg/m^2, Der p 1 levels remained more than 1000-fold lower in Tokelau (data not shown). Floor Der f 1 levels were higher in Tokelau while Der f 1 levels were similar to New Zealand.

All New Zealand dust samples (except one for Fel d 1) had detectable Fel d 1 and Can f 1 levels, compared to 73.9% and

49.0%, respectively, in Tokelau. Bla g 2 was also more commonly detected in New Zealand dust samples. Blo t 5 was only detected in two Tokelau floor dust samples and in one floor and two bedding dust samples in New Zealand.

Endotoxin levels were significantly higher in bedding dust samples from Tokelau while floor endotoxin levels were non-statistically lower in Tokelau (Table 2).

Discussion

This study has confirmed that Tokelau is a unique low indoor allergen environment at sea level. Only about one third of floor and bedding dust samples from Tokelau had detectable Der p 1 levels and even those detected levels were significantly lower than in New Zealand. More importantly, Der p 1 levels in Tokelau were more than 1000-fold lower than in New Zealand. The New Zealand Der p 1 levels were similar to levels we have previously described in New Zealand homes [8].

More than half of the Tokelauan bedding dust samples showed evidence of *Dermatophagoides farinae* colonization, but even then the levels of Der f 1 were very low compared to reported levels around the world. For example, the geometric mean Der f 1 level in bedding in Tokelau was 0.12 μg/g (95% CI: 0.08–0.19) and only 6.5% of the bedding dust samples returned a Der f 1 level of >2.0 μg/g. This compares to 22.4% of bedding samples in Boston, USA having Der f 1 levels of >2.0 μg/g [9].

The animal allergens Fel d 1 and Can f 1 were significantly lower in Tokelau compared to New Zealand. This is not surprising as cats and dogs were eradicated in the 1950s, although feral cats have recently started to re-appear in Tokelau. These allergens probably originate from imported clothing and mats. It has previously been shown that clothing is an important source of cat allergen [10] and that cat allergen can thus be introduced in an environment totally devoid of cats [11].

Exposure to high levels of cockroach allergens among children with known sensitivity to cockroach causes significant morbidity [12]. However, Bla g 2 was only detected in one floor dust sample from Tokelau and none in bedding, while in New Zealand, although at low levels, Bla g 2 was detected in 10 floor and 11 bedding dust samples. A limitation is that we did not measure allergens from American or Oriental cockroaches. However, in New Zealand *Blattilla germanica* is the dominant cockroach species.

Tokelau has a tropical climate and it is possible that other mite species could have been more dominant than either *Dermatophagoides pteronyssinus or farinae*. *Blomia tropicalis* has emerged as a dominant mite species in tropical environments [13]. However, we were only able to detect very low Blo t 5 in two floor and no bedding dust samples from Tokelau, while in New Zealand Blo t 5 was detected in only three dust samples.

Levels of endotoxin were significantly higher in bedding from Tokelau compared to New Zealand. These significant higher endotoxin levels may be due to the close proximity of livestock and the use of mats, rather than mattresses. Exposure to high levels of endotoxin may confer a protective effect on the development of atopy and the subsequent development of atopic disease [14, 15].

Thus, in this study we have shown that Tokelau is a natural low allergen environment at sea level but has relatively high levels of endotoxin. The low HDM allergen levels are most likely due to natural ventilation in their homes and the complete absence of carpets and conventional bedding materials. Traditional Tokelau housing consists of open-plan living areas with natural ventilation through open window spaces compared to generally poorly constructed wooden houses fitted with carpets in New Zealand [16]. Carpets and mattresses are a significant source of allergens [8] and an ideal breeding environment for HDMs due to an unlimited food supply and favourable microclimate. Furthermore, the Tokelau atolls, being made entirely of coral, supports relatively few species of plants with a complete absence of common grasses such as Timothy or Rye, both common environmental allergens in New Zealand. Thus the lower asthma and atopy prevalence rates of Tokelauans living in Tokelau in the 1970s and 1980s could well be related to the virtual absence of common indoor allergens exposures.

Given the very low indoor allergen levels and the relatively high endotoxin levels, Tokelau represents a unique natural environment to explore the acquisition of atopy and the development of allergic disease. Similarly, Tokelau is an interesting environment in which to study the effects of secondary allergen avoidance among those with established disease. Previous studies on intensive HDM allergen avoidance in a hospital setting and at high altitude demonstrated clinical effectiveness [17, 18]. However, those studies have been criticized in that intensive medical attention could have caused bias. Anecdotally, there are many reports of Tokelauan families where children and adults have suffered from severe asthma in New Zealand only to experience a complete remission of their disease upon return to Tokelau. It would be of interest to examine this effect among allergic asthmatics who return to Tokelau for prolonged periods.

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References

1 Illi S, von Mutius E, Lau S et al. The pattern of atopic sensitization is associated with the development of asthma in childhood. J Allergy Clin Immunol 2001; 108:709–14.
2 Sears MR, Herbison GP, Holdaway MD, Hewitt CJ, Flannery EM, Silva PA. The relative risks of sensitivity to grass pollen, house dust mite and cat dander in the development of childhood asthma. Clin Exp Allergy 1989; 19:19–24.
3 Sawyer G, Kemp T, Shaw R et al. Biological pollution in infant bedding in New Zealand: high allergen exposure during a vulnerable period. J Allergy Clin Immunol 1998; 102:765–70.
4 The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Worldwide variation in prevalence of symptoms of asthma, alergic rhinoconjunctivitis, and atopic eczema: ISAAC. Lancet 1998; 351:1125–32.

5 Stanhope JM, Prior IA. The Tokelau Island migrant study: prevalence of various conditions before migration. Int J Epidemiol 1976; 5:259–66.
6 Waite DA, Eyles EF, Tonkin SL, O'Donnell TV. Asthma prevalence in Tokelauan children in two environments. Clin Allergy 1980; 10:71–5.
7 Crane J, O'Donnell T, Beaumont A, Coleman E. Asthma, bronchial hyperresponsiveness and atopy in Tokelauan children in two environments. A comparison of indigenous children with New Zealand migrants (Abstract). Austr N Z Med J 1990; 20 (Suppl 1):536.
8 Wickens K, Siebers R, Ellis I et al. Determinants of house dust mite allergen in homes in Wellington, New Zealand. Clin Exp Allergy 1997; 27:1077–85.
9 Chew GL, Burge HA, Dockery DW, Muilenberg ML, Weiss ST, Gold DR. Limitations of a home characteristics questionnaire as a predictor of indoor allergen levels. Am J Respir Crit Care Med 1998; 157:1536–41.
10 Patchett K, Lewis S, Crane J, Fitzharris P. Cat allergen (Fel d 1) levels on school children's clothing and in primary classrooms in Wellington, New Zealand. J Allergy Clin Immunol 1997; 100:755–9.
11 Siebers R, Weinstein P, Fitzharris P, Crane J. House-dust mite and cat allergens in the Antarctic. Lancet 1999; 353:1942.
12 Rosenstreich DL, Eggleston P, Kattan M et al. The role of cockroach allergen in causing morbidity among inner-city children with asthma. N Engl J Med 1997; 336:1356–63.
13 Chew FT, Zhang L, Ho TM, Lee BW. House dust mite fauna of tropical Singapore. Clin Exp Allergy 1999; 29:201–6.
14 von Mutius E, Braun-Fahrlander C, Schierl R et al. Environmental exposure to endotoxin or other bacterial compounds might protect against the development of atopy. Clin Exp Allergy 2000; 30:1230–4.
15 Braun-Fahrlander C, Riedler J, Herz U et al. Environmental exposure to endotoxin and its relation to asthma in school-age children. N Engl J Med 2002; 347:869–77.
16 Howden-Chapman P, Pene G, Crane J et al. Open houses and closed rooms: Tokelau housing in New Zealand. Health Educ Behav 2000; 27:351–62.
17 Platts-Mills TA, Tovey ER, Mitchell EB, Moszoro HB, Nock P, Wilkins SR. Reduction of bronchial hyperreactivity during prolonged allergen avoidance. Lancet 1982; 2:675–8.
18 Peroni DG, Boner AL, Vallone G, Antolini I, Warner JO. Effective allergen avoidance at high altitude reduces allergen-induced bronchial hyperresponsiveness. Am J Resp Crit Care Med 1994; 149:1442–6.