

Pet shop workers: exposure, sensitization, and work-related symptoms

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Abstract

Background: Allergy to laboratory animals is a well-known occupational hazard. The aim was to investigate the frequency of allergic sensitization and respiratory symptoms among pet shop staff and to document their work environment.

Methods: Subjects ($n = 59$) from 24 pet shops were investigated with a questionnaire and lung function tests and skin prick tests against a panel of common inhalant and pet shop allergens. Blood samples were taken for immunoglobulin E (IgE) and IgE antibodies against Phadiatop and specific pet shop allergens. Personal airborne rodent allergen ($n = 40$) and endotoxin exposure ($n = 40$) was measured during work. Airborne rodent allergens were also collected using petri dishes at work ($n = 40$) and at home ($n = 45$).

Results: Fifty-three percent reported nasal symptoms, 34% eye symptoms, and 22% had experienced symptoms indicating asthma. However, only four workers (7%) were previously diagnosed with asthma. One-third reported respiratory symptoms at work, mostly against rodents, birds, insects, and hay, and 29% were sensitized to work-related allergens, mainly rodents and fodder insects, e.g., *Zophobas*. Atopy and total IgE > 100 kU/l increased prevalence of pet shop sensitization [prevalence ratio (PR) 17 and 5.5, respectively], and atopy increased work-related symptoms (PR 3.2). Endotoxin levels were similar between shops with and without rodents. Exposure to animals outside of work was extensive.

Conclusions: A third of the pet shop workers reported airway symptoms at work or were sensitized, sometimes to unusual pet shop allergens, especially among atopics. The findings stress the importance of improving the knowledge of health risks and allergen avoidance measures among pet shop staff.

Laboratory animal allergy is a well-known occupational hazard (1). Usually, between 10% and 50% of laboratory staff exposed to rodents develop symptoms or immunoglobulin E (IgE) antibodies to animal allergens, the majority within the first few years. Several studies have found a dose–response relationship, stronger for atopics than nonatopics (2, 3). Nowadays, in several countries, specific occupational health regulations are in force, with medical examinations and staff education, while animal facilities and work practices are planned so as to minimize allergen exposure (3–5).

Although it is likely that other workers with rodent exposure are at risk of developing allergy, studies of such occupa-

tions are scant. In veterinarians, allergic symptoms or sensitization to work allergens were found to be common (6–8). Concerning pet shop staff, only a few case reports exist, in which fodder insect larvae [chironomids (9, 10) and *Tenebrio molitor*, mealworm (11)] have been shown to cause occupational asthma or other symptoms. A case of hypersensitivity during both inhalation and ingestion of mealworm and *Zophobas morio* (superworm) has been reported (12). Even reptiles may cause allergy: a first case report of sensitization to a pet Iguana was published in 2000 (13). Furthermore, bird exposure may cause extrinsic allergic alveolitis (14).

Occupational exposure in the pet shop environment to a number of allergen sources, as well as microbial agents such as endotoxin that may induce occupational respiratory symptoms (15), might influence the risk of workers to developing allergy and respiratory symptoms. As little is known regarding occupational health among pet shop workers, the purpose of this study was explorative: to investigate the frequency of allergic sensitization and respiratory symptoms among pet shop staff and to document the work environment.

Methods

Pet shops

An open invitation to participate in a study of pet shop environment and health was sent to zoological trade companies around Stockholm, Sweden. Of the 48 pet shops that responded, 28 (58%) gave consent to a visit, and workers from 24 shops agreed to answer a questionnaire (16) and to medical examinations including skin prick tests, blood sampling, and lung function tests. These 24 pet shops did not differ statistically from the other 24 pet shops with respect to type of shop, but had 1.4 more employees per shop.

The pet shops were divided into categories: shops with rodents (species belonging to *Rodentia*: rats, mice, hamsters, guinea pigs, chinchilla, degus, and gerbils, besides other animal species); shops with other animals (without rodents); and shops with pet supplies (no animals for sale).

A total of 59 of the 83 (71%) eligible persons (adults who worked more than weekends) volunteered to take part in the medical examinations.

The study was approved by the Ethical Board at Karolinska Institutet. In all stages of the study, it was emphasized that all participation of both pet shops and individuals was voluntary.

Skin prick tests

Skin prick testing (SPT) was with a panel of common airborne allergens: birch, timothy grass, mugwort, dog, cat, horse, moulds (*Cladsporium herbarum*, *Alternaria alternata*), and house dust mites (*Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*) (ALK-Abello A/S, Hørsholm, Denmark) and a panel of pet shop allergens: guinea pig, rabbit, hamster, rat, budgerigar, shrimp, and storage mites (*Lepidoglyphus destructor*, *Acarus siro* from Allergopharma, Reinbek, Germany). Wheal diameters ≥ 3 mm were considered positive.

IgE and IgE antibodies

Blood samples were assayed for IgE antibodies (kU_A/l) against mealworm beetle (*Tenebrio molitor*, Ro211), gerbil epithelia (Re209), *Chironomus* larvae (i73), and a bird mix (ex72) as well as *Zophobas* droppings and larvae (MIAB, Uppsala, Sweden) and serum IgE (kU/l) and Phadiatop™ using the ImmunoCAP™ system (Phadia AB, Uppsala, Sweden). Immunoglobulin E antibody levels of ≥ 0.35 kU_A/l were considered positive. Immunoglobulin E antibodies against rat

and mouse urinary allergens (MUA) respectively were determined using an in-house enzyme-linked immunosorbent assay (ELISA) with a sensitivity of 0.1 kU/l (5).

Lung function tests

All subjects were tested using a Vitalograph spirometer for vital capacity (VC), forced vital capacity (FVC), and FEV₁ (forced expiratory volume in 1 s), and values were compared with the expected values (17, 18).

Allergen and endotoxin sampling

One or two workers in each pet shop (depending upon staff available) carried two portable pumps (SKC Inc., Eighty Four, PA, USA) each for assessment of inhalable allergens ($n = 40$) and endotoxins ($n = 40$), collected on 1- μ m filters at 2 l/min during 5 h of normal work activity (19). Airborne sedimenting allergens were also collected during 1 week as described previously (20) using petri dishes ($n = 40$) coated with teleostean gelatin (Sigma, St Louis, MO, USA) at 2%, placed at the counters and, if present, in the separate animal rooms. Staff was instructed to close the petri dishes after 7 days, seal them, and send them to us by post.

To study possible allergen transfer from the shops to homes, the staff was also given petri dishes and asked to place them opened on a table beside their bed, to collect airborne dust sedimenting over 7 days ($n = 45$).

Elution of air and petri dish samples for allergen measurement

Air samples were eluted as described previously (19). Dust was collected from petri dish base and lid by repeated pipetting with 2 ml extraction buffer (PBS, 0.5% Tween 20, 0.15% Kathon CG, 1% BSA). Samples were rotated for 2 h, centrifuged at 1000 *g* for 10 min, and supernatants were stored at -20°C .

Analysis of airborne allergens

Air and petri dish samples were analyzed for rat urinary allergen Rat n 1 (RUA) and mouse urinary allergen Mus m 1 (MUA) by ELISA assay, as described previously (19, 21). Analysis of cat allergen (Fel d 1) was performed using commercial reagents (Indoor Biotechnologies, Charlottesville, VA, USA) as described (20). Samples near or below the limit of detection (< 0.2 ng/ml) were reassayed using AMPAK signal amplification (Dakopatts AB, Helsingborg, Sweden) according to the manufacturers recommendations. Detection limits were 10 pg/ml or about 20 pg/m³ for rodent allergens and 5 pg/ml (10 pg/m³) for cat allergen, respectively.

Analysis of endotoxin

Air filters were extracted in 2 ml sterile water and 0.05% Tween 20 in sterile Falcon tubes (2085; Becton Dickinson, Stockholm, Sweden), rotated for 1 h, and centrifuged at 1000 *g* for 10 min to remove debris. The supernatants were stored in sterile cryotubes (Nunc A/S, Roskilde, Denmark) at

–20°C. A colorimetric limulus amebocyte lysate (LAL) test QCL-1000 (Bio Whittaker, Walkersville, MD, USA) was used to determine endotoxins as described by the manufacturer. The detection limit was 0.33 EU/m³ at 5 h of air sampling.

Statistics

Main outcome variables were work-related allergic symptoms and sensitization (SPT or IgE antibodies) to pet shop allergens.

Work exposure assignment

Mean personal airborne and sedimenting dust RUA and MUA levels, respectively, and airborne endotoxin values for each shop were allocated to each study participant from that shop.

Analyses were mainly performed using STATVIEW (v 5.01; sas Institute, Solna, Sweden). Values that were not normally distributed are presented as median with 25–75th percentiles. Chi-square test (or Fisher's exact test) was used to test correlation between factors. Nonparametric tests were used to test exposure differences between groups. To analyze risk factors and presence of work symptoms or sensitization, for dichotomous variables, prevalence ratios (PR) with 95% confidence interval (CI) were calculated (EpiInfo, OpenEpi v 2.3; CDC, Atlanta, GA, USA). For continuous variables, Mann–Whitney *U*-test was used. *P* < 0.05 was considered significant.

Results

Pet shops and pet shop animals

Of the 24 investigated shops, 20 had animals present of which 17 had rodents; 16 had specific animal rooms. The remaining four shops sold pet food and other pet articles. The pet shops varied in size between 42 and 350 m² (median 150). The shops had a wide range of animals, and most had aquaria with fish (18 shops). Insects (17 shops), mealworm (*Tenebrio molitor*), superworm (*Zophobas morio*) (Fig. S1), and chironomid midge (Chironomidae) larvae, crickets, cockroaches, etc.) were sold or used as fodder for fish or reptiles. Various rodent species (17 shops) and rabbits (15 shops) were commonly present, but also reptiles (13 shops) and amphibians (12 shops). Although dogs are forbidden to sell in pet shops in Sweden, they were often present (14 shops) as staff brought their own dogs to work.

Pet shop workers and pet exposure

The participants had worked with animals on average 9.4 years (range 1–36 years). Their mean age was 31.4 years (range 17–59 years), and 24% were current smokers (Table 1).

Most pet shop workers had extensive lifetime animal exposure at home – all had owned pets, 74% at least three types of animals, and 24% had at least had seven. Dogs (83%), cats (76%), horses/regular horse riding (60%), hamsters (47%), and rabbits (45%) were the most common. Current pet exposure (in the home or outside of work in the last year) was most common to cats (57%), dogs (55%), and fish (53%),

Table 1 Pet shop workers (*n* = 59)*

Characteristics	<i>N</i> (%) or mean (±SD)
Age (±SD) (years)	31.4 (±9.9)
Women (%)	39 (66)
Smoking (%)	14 (24)
Phadiatop or SPT positive to common inhalant allergens (%)	17 (29)
Asthma, doctor's diagnosed	4 (7)
Wheezing	20 (35)
Asthma according to symptoms†	13 (22)
Nasal (blocked, runny nose, or sneezing)	31 (53)
Eye (runny, itchy eyes)	20 (34)
Work-related	
Years worked with animals	9.4 (±7.4)
SPT positive to pet shop allergen panel (%)	13 (22)
IgE antibody to pet shop allergen panel (%)	10 (17)
SPT or serum positive to pet shop panel (%)	16 (27)
Allergic symptoms at work	
‘Yes’	20 (34)
‘Don't know’	8 (14)
Nasal (blocked or runny nose or sneezing)	23 (40)
Eye (irritated eyes)	13 (22)
Chest (coughing, wheezing, chest tightness)	13 (22)
Skin symptoms	13 (22)

SPT, Skin prick testing.

*One subject did not fill out the questionnaire, one subject failed to produce an acceptable lung function test, and one subject refused blood sampling (*n* = 58 for this information).

†According to questionnaire: ‘Yes’ to attacks of tightness of the chest and/or wheezing, and these symptoms occur without an airway infection, and/or these symptoms may occur during exercise.

although birds or reptiles were also common as pets (both 35%). Almost all reported having had exposure to animals from an early age, and mean exposure time for dogs was 16 years, cat 14 years, and horses and rabbits both 10 years.

Allergen and endotoxin exposure

Personal occupational aeroallergen exposure

The RUA levels were generally low, only 23% were above detection limit, whereas MUA exposure was measurable in 75% of the pet shops (Fig. 1). Levels in pet shops without rodents were mainly below detection limit. Airborne Fel d 1 was found in all pet shops.

Personal occupational endotoxin exposure

Endotoxin levels (*n* = 40) were not significantly different between pet shops with rodents and shops with only other animals and were very low in supply shops (Fig. 1).

Sedimenting aeroallergens at work and at home

Sedimenting airborne dust collected at the sales counters and in the animal rooms using petri dishes (*n* = 40) varied greatly between shops (<0.3–642 ng/m²/day for RUA,

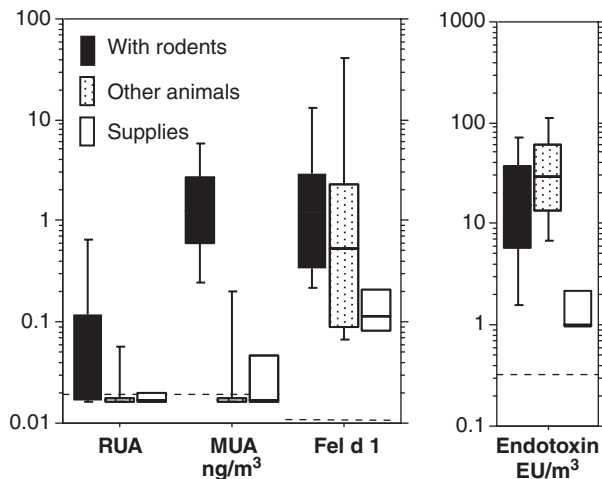


Figure 1 Airborne levels of allergens and endotoxin in pet shops selling rodents, other animals or pet supplies only. Samples were collected using person-carried pumps during work. Box plots. Detection limits are indicated with hatched lines.

<0.3–3091 ng/m²/day for MUA, and 0.5–566 ng/m²/day for Fel d 1, respectively). Levels of rodent allergen were undetectable in pet shops without rodents. In shops with rodents, rodent allergen levels were higher (Wilcoxon signed rank test) in the animal rooms than at the counters, median 54.8 vs 1.2 for RUA ($P = 0.0006$) and 550 vs 60.3 ng/m²/day for MUA ($P = 0.003$), respectively. Fel d 1 levels were instead lower in the animal rooms: 18.7 vs 37.4 ng/m²/day ($P = 0.03$).

Sedimenting dust collected in bedrooms ($n = 45$) showed higher rodent or cat allergen levels in homes with the respective animals (data not shown). There were indications of allergen transfer between shops and homes: MUA levels were a median 3.5-fold higher ($P = 0.02$) in samples from homes of nonmouse owners who worked with mice, than in homes of workers from shops without mice. The home median levels of MUA were about one-tenth of shop counter levels, while

Fel d 1 was found in shops at about one-tenth of the levels of the homes with cats.

Sensitization and symptoms

Forty-one persons worked in shops with rodents, 13 in shops without rodents, and five in pet supply shops. Atopy, defined as a positive Phadiatop test or a positive SPT to a common inhalant allergen, was found in 29%. Positive Phadiatop and SPT were highly related ($P < 0.001$), and SPT positivity was most common against dogs (17%), timothy grass (15%), and birch and cat (both 12%).

Immunoglobulin E sensitization to pet shop allergen panels was found in 13 (SPT) and 10 (serum) persons, respectively, in total 16 (27%) of pet shop workers (Table 2). The highest IgE levels were found against *Zophobas* larvae and their droppings, and against mealworm.

A majority of pet shop workers reported nasal (53%) and/or eye (34%) symptoms, and 22% reported wheezing or tightness of the chest not related to infections, indicating asthma. Wheezing ever was reported by 35%. However, only four subjects had a doctor's diagnosis of asthma. Lung function values were on average slightly lower than expected: 91.4% (SD ± 10.9) of expected for VC, 93.3% (± 11.1) for forced VC, and 94.8% (± 13.3) for FEV₁. The average ratio FEV₁/VC was normal, 101.5% (± 7.2) of expected, but 21 persons had a ratio below 80% (of which six persons were below 75%).

A third of pet shop workers (20 persons) reported having experienced allergic symptoms at work, mostly against rodents and rabbits, birds, insects and chironomids, and hay. Four subjects spontaneously mentioned strong work exposure reactions such as edema, flush, rash, and asthma attack. A further eight persons were uncertain whether symptoms were related to work (Table 1).

Risk factors in relation to sensitization and symptoms

Sensitization to the pet shop allergens and allergic symptoms at work were highly correlated, $P = 0.002$. Immunoglobulin E to pet shop allergens significantly increased the prevalence

Table 2 Results of work immunoglobulin E (IgE) sensitization tests: skin prick testing ($n = 59$) and IgE antibody (kUA/l) in serum to pet shop allergens, kU/l ($n = 58$)

Pet shop allergen panel	No. positive (%)	Pet shop allergen panel	No. positive (>0.35 kUA/l) (%)	Lowest – highest IgE antibody values
Skin prick test		IgE antibody in serum		
Rat	6 (10)	Rat urinary allergen	5 (9)	<0.1–3.9
Guinea pig	5 (8)	Mouse urinary allergen	5 (9)	<0.1–39.7
Lepidoglyphus destructor	5 (8)	Zophobas droppings	5 (9)	<0.35–212.9
Rabbit	3 (5)	Zophobas larvae	4 (7)	<0.35–143.4
Hamster	3 (5)	Mealworm (<i>Tenebrio molitor</i>)	3 (5)	<0.35–99.7
Acarus siro	3 (5)	Gerbil epithelium	2 (3)	<0.35–4.0
Budgerigar	2 (3)	Chironomid larvae	2 (3)	<0.35–9.3
Shrimp	0	Bird mix	1 (2)	<0.35–0.64

Table 3 Risk factors and symptoms at work or sensitization to work allergen panel

Risk Factors	Proportion with symptoms at work without risk factor <i>n</i> (%)	Proportion with symptoms at work with risk factor <i>n</i> (%)	Prevalence Ratio 95% CI	Proportion with sensitization to work allergens without risk factor <i>n</i> (%)	Proportion with sensitization to work allergens with risk factor <i>n</i> (%)	Prevalence Ratio 95% CI
Personal factors						
Sensitization to work allergens	9/43 (21)	11/15 (73)	3.5 (1.8–6.8)**	–	–	–
Work symptoms†	–	–	–	5/39 (13)	11/20 (55)	4.3 (1.7–11)**
Male sex	11/39 (28)	9/19 (47)	1.7 (0.8–3.3)	7/39 (18)	9/20 (45)	2.5 (1.1–5.7)*
Smoking, current	17/44 (39)	3/14 (21)	0.55 (0.19–1.6)	12/44 (27)	3/14 (21)	OR 0.79 (0.26–2.4)
Atopy (Skin prick testing and/or Phadiatop positive)	9/42 (21)	11/16 (69)	3.2 (1.6–6.2)**	2/42 (5)	14/17 (82)	OR 17 (4.4–68)***
IgE > 100 kU/l	15/50 (30)	4/7 (57)	1.9 (0.9–4.1)	8/50 (16)	7/8 (88)	OR 5.5 (2.8–11)***
Work exposure						
Work years with animals	6.5 (4.0–13)	7.5 (3.5–13)	0.64	7.0 (3.5–13)	7.0 (4.0–13)	0.85
Endotoxin (EU/m ³)	13.6 (9.5–50.8)	13.9 (9.5–39.5)	0.70	13.8 (9.5–48.4)	12.7 (3.8–29.3)	0.34
RUA (ng/m ³)	<0.02 (<0.02–0.18)	<0.02 (<0.02–0.09)	0.92	<0.02 (<0.02–0.24)	<0.02 (<0.02–<0.02)	0.33
MUA (ng/m ³)	0.84 (0.17–2.17)	0.92 (0.03–3.22)	0.98	0.84 (0.06–1.80)	1.72 (0.52–3.57)	0.11
RUA at counter (ng/m ² /day)	0.9 (<0.2–2.4)	1.7 (<0.2–3.4)	0.31	0.95 (<0.2–2.8)	1.1 (0.37–2.5)	0.71
MUA at counter (ng/m ² /day)	60.3 (9.8–238)	21.4 (9.2–79.3)	0.28	23.6 (8.6–190)	60.0 (10.3–165)	0.99

* < 0.05; ** < 0.001; *** < 0.0001. MUA, mouse urinary allergen; RUA, rat urinary allergen.

#Mann–Whitney *U*-test.†Workers who have answered 'No' (*n* = 30) or 'Don't know' (*n* = 8) to whether their symptoms were work-related are grouped as without work-related symptoms.

of work symptoms ($PR = 3.5$) and *vice versa* ($PR = 4.3$) (Table 3). Atopy strongly increased pet shop panel sensitization prevalence ($PR = 17$) and work symptoms ($PR = 3.2$). Immunoglobulin E was significantly ($P < 0.001$) higher among pet shop sensitized workers vs nonsensitized: median (25th–75th percentiles) 90 (63–304) and 16 (7–47) kU/l, respectively. IgE > 100 kU/l was also significantly related to sensitization ($PR = 5.5$), as was male sex ($PR = 2.5$). There were no correlations between allergen levels or endotoxin levels and either work symptoms or work sensitization.

Discussion

This study is the first to investigate exposure, work-related allergic sensitization and respiratory symptoms among pet shop workers. We found that a large proportion of pet shop workers reported airway symptoms at work and that about a third was IgE sensitized to allergens present in pet shops. Sensitization to pet shop allergens increased the risk (PR) of symptoms at work 3.5-fold, and work symptoms increased the risk of sensitization 4.3-fold. The strongest risk factor for sensitization to pet shop allergens was atopy ($PR = 17$), which also had an impact on work symptoms ($PR = 3.2$). Elevated IgE also increased risk of sensitization ($PR = 5.5$). The proportion of atopics (29%) was similar to that observed in Swedish blood donors (26%) (22). Although this is a cross-sectional survey, limiting the possibility to claim causality, similar results (but with lower PR s) have been found in longitudinal studies of laboratory animal workers exposed to rodents (16, 23). It is possible that some of the high correlations between positive IgE tests are caused by cross-reactivity between related allergens, such as various mite species or serum albumins (24).

The most common pet shop-sensitizing allergens were rat and MUAs along with *Zophobas*. The highest IgE levels were actually found against *Zophobas* larvae and their droppings. This large mealworm, used as reptile fodder in pet shops, and chironomids and crickets, were reported by several workers to have caused occasional strong allergic reactions.

We also found that pet shop workers may be exposed to many animal allergens both at work and at home and that allergens may be spread from work to the home and *vice versa*. The constant high exposure to organic dust or components such as endotoxin may conceivably be connected to the slightly decreased lung function found in these lifelong animal-exposed workers, similarly to farmers (25). However, the endotoxin levels were well below such measured in several other occupational environments, causing for instance organic toxic dust syndrome (26). It is possible that endotoxin or other microbial exposures have prevented more workers to develop sensitization or symptoms or conversely that the levels were mostly too low to promote tolerance. In a recent study of laboratory animal workers, we found that high rodent allergen and endotoxin exposure induces a systemic engagement with increased levels of circulating neutrophils, monocytes, and interleukin-6, unrelated to allergic sensitization [Blidberg 2010 submitted].

Although this is the largest study of pet shop work to date, the numbers do not allow sensitization and symptom analysis by shop type. Furthermore, several workers had because of work-related symptoms changed their exposure making such an analysis precarious to interpret. The fact that we did not find exposure to be related to work symptoms or sensitization may thus be a healthy worker effect, because of work adaption, with avoidance of animals, tasks or workplaces causing problems.

Both under- and overrepresentations of allergic workers are possible. Several shop owners who responded to the invitation but declined participation had one-person companies, for whom it is understandably difficult to close the shop to undergo allergy and lung function tests. Nevertheless, this study represents the first in which a large number of pet shops have been investigated, including personal exposure measurements, allergy, and lung function tests. A further strength is that the worker's exposure at home has been studied.

Although 22% of the workers reported wheezing or tightness of the chest not in connection with an infection, only four (7%) had prior to our study received a doctor's diagnosis of asthma and obtained treatment. Thus, too few with symptoms indicative of asthma have undergone allergy or lung function tests and received a diagnosis, let alone medication or preventive advice.

In conclusion, pet shop workers are exposed to a variety of allergens, which constitute a risk factor for allergic sensitization and symptoms. The findings stress the importance of improved knowledge of health risks among pet shops workers and possible allergen avoidance measures. For clinicians, it is important to remember that fodder insects such as *Zophobas*, or chironomids, may cause allergy and asthma in pet shop workers.

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Authors' contributions

AR was responsible for the project, participated in all stages and tasks, and was main author of the manuscript. MO contributed to the planning of the study was responsible for the data collection and analysis of samples from pet shops and reviewed the manuscript. MH was responsible for the data collection and analysis of samples from the workers and reviewed the manuscript. SGOJ contributed to the IgE analyses and provided critical review of the manuscript. MvH contributed to the IgE analyses and provided critical review during the project and of the manuscript.

Conflicts of interest

The authors (AR, MO, MH, SGOJ, and MvH) declare no conflicts of interest.

Supporting Information

Additional Supporting Information may be found in the online version of this article found at: <http://www.wileyonlinelibrary.com>.

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Figure S1. Pet shop worker showing Zophobas larvae sold as reptile fodder.

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Pet shop workers: exposure, sensitization, and work-related symptoms

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Abstract

Background: Allergy to laboratory animals is a well-known occupational hazard. The aim was to investigate the frequency of allergic sensitization and respiratory symptoms among pet shop staff and to document their work environment.

Methods: Subjects ($n = 59$) from 24 pet shops were investigated with a questionnaire and lung function tests and skin prick tests against a panel of common inhalant and pet shop allergens. Blood samples were taken for immunoglobulin E (IgE) and IgE antibodies against Phadiatop and specific pet shop allergens. Personal airborne rodent allergen ($n = 40$) and endotoxin exposure ($n = 40$) was measured during work. Airborne rodent allergens were also collected using petri dishes at work ($n = 40$) and at home ($n = 45$).

Results: Fifty-three percent reported nasal symptoms, 34% eye symptoms, and 22% had experienced symptoms indicating asthma. However, only four workers (7%) were previously diagnosed with asthma. One-third reported respiratory symptoms at work, mostly against rodents, birds, insects, and hay, and 29% were sensitized to work-related allergens, mainly rodents and fodder insects, e.g., *Zophobas*. Atopy and total IgE > 100 kU/l increased prevalence of pet shop sensitization [prevalence ratio (PR) 17 and 5.5, respectively], and atopy increased work-related symptoms (PR 3.2). Endotoxin levels were similar between shops with and without rodents. Exposure to animals outside of work was extensive.

Conclusions: A third of the pet shop workers reported airway symptoms at work or were sensitized, sometimes to unusual pet shop allergens, especially among atopics. The findings stress the importance of improving the knowledge of health risks and allergen avoidance measures among pet shop staff.

Laboratory animal allergy is a well-known occupational hazard (1). Usually, between 10% and 50% of laboratory staff exposed to rodents develop symptoms or immunoglobulin E (IgE) antibodies to animal allergens, the majority within the first few years. Several studies have found a dose–response relationship, stronger for atopics than nonatopics (2, 3). Nowadays, in several countries, specific occupational health regulations are in force, with medical examinations and staff education, while animal facilities and work practices are planned so as to minimize allergen exposure (3–5).

Although it is likely that other workers with rodent exposure are at risk of developing allergy, studies of such occupa-

tions are scant. In veterinarians, allergic symptoms or sensitization to work allergens were found to be common (6–8). Concerning pet shop staff, only a few case reports exist, in which fodder insect larvae [chironomids (9, 10) and *Tenebrio molitor*, mealworm (11)] have been shown to cause occupational asthma or other symptoms. A case of hypersensitivity during both inhalation and ingestion of mealworm and *Zophobas morio* (superworm) has been reported (12). Even reptiles may cause allergy: a first case report of sensitization to a pet Iguana was published in 2000 (13). Furthermore, bird exposure may cause extrinsic allergic alveolitis (14).

Occupational exposure in the pet shop environment to a number of allergen sources, as well as microbial agents such as endotoxin that may induce occupational respiratory symptoms (15), might influence the risk of workers to developing allergy and respiratory symptoms. As little is known regarding occupational health among pet shop workers, the purpose of this study was explorative: to investigate the frequency of allergic sensitization and respiratory symptoms among pet shop staff and to document the work environment.

Methods

Pet shops

An open invitation to participate in a study of pet shop environment and health was sent to zoological trade companies around Stockholm, Sweden. Of the 48 pet shops that responded, 28 (58%) gave consent to a visit, and workers from 24 shops agreed to answer a questionnaire (16) and to medical examinations including skin prick tests, blood sampling, and lung function tests. These 24 pet shops did not differ statistically from the other 24 pet shops with respect to type of shop, but had 1.4 more employees per shop.

The pet shops were divided into categories: shops with rodents (species belonging to *Rodentia*: rats, mice, hamsters, guinea pigs, chinchilla, degus, and gerbils, besides other animal species); shops with other animals (without rodents); and shops with pet supplies (no animals for sale).

A total of 59 of the 83 (71%) eligible persons (adults who worked more than weekends) volunteered to take part in the medical examinations.

The study was approved by the Ethical Board at Karolinska Institutet. In all stages of the study, it was emphasized that all participation of both pet shops and individuals was voluntary.

Skin prick tests

Skin prick testing (SPT) was with a panel of common airborne allergens: birch, timothy grass, mugwort, dog, cat, horse, moulds (*Cladsporium herbarum*, *Alternaria alternata*), and house dust mites (*Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*) (ALK-Abello A/S, Hørsholm, Denmark) and a panel of pet shop allergens: guinea pig, rabbit, hamster, rat, budgerigar, shrimp, and storage mites (*Lepidoglyphus destructor*, *Acarus siro* from Allergopharma, Reinbek, Germany). Wheal diameters ≥ 3 mm were considered positive.

IgE and IgE antibodies

Blood samples were assayed for IgE antibodies (kU_A/l) against mealworm beetle (*Tenebrio molitor*, Ro211), gerbil epithelia (Re209), *Chironomus* larvae (i73), and a bird mix (ex72) as well as *Zophobas* droppings and larvae (MIAB, Uppsala, Sweden) and serum IgE (kU/l) and Phadiatop™ using the ImmunoCAP™ system (Phadia AB, Uppsala, Sweden). Immunoglobulin E antibody levels of ≥ 0.35 kU_A/l were considered positive. Immunoglobulin E antibodies against rat

and mouse urinary allergens (MUA) respectively were determined using an in-house enzyme-linked immunosorbent assay (ELISA) with a sensitivity of 0.1 kU/l (5).

Lung function tests

All subjects were tested using a Vitalograph spirometer for vital capacity (VC), forced vital capacity (FVC), and FEV₁ (forced expiratory volume in 1 s), and values were compared with the expected values (17, 18).

Allergen and endotoxin sampling

One or two workers in each pet shop (depending upon staff available) carried two portable pumps (SKC Inc., Eighty Four, PA, USA) each for assessment of inhalable allergens ($n = 40$) and endotoxins ($n = 40$), collected on 1- μ m filters at 2 l/min during 5 h of normal work activity (19). Airborne sedimenting allergens were also collected during 1 week as described previously (20) using petri dishes ($n = 40$) coated with teleostean gelatin (Sigma, St Louis, MO, USA) at 2%, placed at the counters and, if present, in the separate animal rooms. Staff was instructed to close the petri dishes after 7 days, seal them, and send them to us by post.

To study possible allergen transfer from the shops to homes, the staff was also given petri dishes and asked to place them opened on a table beside their bed, to collect airborne dust sedimenting over 7 days ($n = 45$).

Elution of air and petri dish samples for allergen measurement

Air samples were eluted as described previously (19). Dust was collected from petri dish base and lid by repeated pipetting with 2 ml extraction buffer (PBS, 0.5% Tween 20, 0.15% Kathon CG, 1% BSA). Samples were rotated for 2 h, centrifuged at 1000 *g* for 10 min, and supernatants were stored at -20°C .

Analysis of airborne allergens

Air and petri dish samples were analyzed for rat urinary allergen Rat n 1 (RUA) and mouse urinary allergen Mus m 1 (MUA) by ELISA assay, as described previously (19, 21). Analysis of cat allergen (Fel d 1) was performed using commercial reagents (Indoor Biotechnologies, Charlottesville, VA, USA) as described (20). Samples near or below the limit of detection (< 0.2 ng/ml) were reassayed using AMPAK signal amplification (Dakopatts AB, Helsingborg, Sweden) according to the manufacturers recommendations. Detection limits were 10 pg/ml or about 20 pg/m³ for rodent allergens and 5 pg/ml (10 pg/m³) for cat allergen, respectively.

Analysis of endotoxin

Air filters were extracted in 2 ml sterile water and 0.05% Tween 20 in sterile Falcon tubes (2085; Becton Dickinson, Stockholm, Sweden), rotated for 1 h, and centrifuged at 1000 *g* for 10 min to remove debris. The supernatants were stored in sterile cryotubes (Nunc A/S, Roskilde, Denmark) at

–20°C. A colorimetric limulus amoebocyte lysate (LAL) test QCL-1000 (Bio Whittaker, Walkersville, MD, USA) was used to determine endotoxins as described by the manufacturer. The detection limit was 0.33 EU/m³ at 5 h of air sampling.

Statistics

Main outcome variables were work-related allergic symptoms and sensitization (SPT or IgE antibodies) to pet shop allergens.

Work exposure assignment

Mean personal airborne and sedimenting dust RUA and MUA levels, respectively, and airborne endotoxin values for each shop were allocated to each study participant from that shop.

Analyses were mainly performed using STATVIEW (v 5.01; sas Institute, Solna, Sweden). Values that were not normally distributed are presented as median with 25–75th percentiles. Chi-square test (or Fisher's exact test) was used to test correlation between factors. Nonparametric tests were used to test exposure differences between groups. To analyze risk factors and presence of work symptoms or sensitization, for dichotomous variables, prevalence ratios (PR) with 95% confidence interval (CI) were calculated (EpiInfo, OpenEpi v 2.3; CDC, Atlanta, GA, USA). For continuous variables, Mann–Whitney *U*-test was used. *P* < 0.05 was considered significant.

Results

Pet shops and pet shop animals

Of the 24 investigated shops, 20 had animals present of which 17 had rodents; 16 had specific animal rooms. The remaining four shops sold pet food and other pet articles. The pet shops varied in size between 42 and 350 m² (median 150). The shops had a wide range of animals, and most had aquaria with fish (18 shops). Insects (17 shops), mealworm (*Tenebrio molitor*), superworm (*Zophobas morio*) (Fig. S1), and chironomid midge (Chironomidae) larvae, crickets, cockroaches, etc.) were sold or used as fodder for fish or reptiles. Various rodent species (17 shops) and rabbits (15 shops) were commonly present, but also reptiles (13 shops) and amphibians (12 shops). Although dogs are forbidden to sell in pet shops in Sweden, they were often present (14 shops) as staff brought their own dogs to work.

Pet shop workers and pet exposure

The participants had worked with animals on average 9.4 years (range 1–36 years). Their mean age was 31.4 years (range 17–59 years), and 24% were current smokers (Table 1).

Most pet shop workers had extensive lifetime animal exposure at home – all had owned pets, 74% at least three types of animals, and 24% had at least had seven. Dogs (83%), cats (76%), horses/regular horse riding (60%), hamsters (47%), and rabbits (45%) were the most common. Current pet exposure (in the home or outside of work in the last year) was most common to cats (57%), dogs (55%), and fish (53%),

Table 1 Pet shop workers (*n* = 59)*

Characteristics	<i>N</i> (%) or mean (±SD)
Age (±SD) (years)	31.4 (±9.9)
Women (%)	39 (66)
Smoking (%)	14 (24)
Phadiatop or SPT positive to common inhalant allergens (%)	17 (29)
Asthma, doctor's diagnosed	4 (7)
Wheezing	20 (35)
Asthma according to symptoms†	13 (22)
Nasal (blocked, runny nose, or sneezing)	31 (53)
Eye (runny, itchy eyes)	20 (34)
Work-related	
Years worked with animals	9.4 (±7.4)
SPT positive to pet shop allergen panel (%)	13 (22)
IgE antibody to pet shop allergen panel (%)	10 (17)
SPT or serum positive to pet shop panel (%)	16 (27)
Allergic symptoms at work	
‘Yes’	20 (34)
‘Don't know’	8 (14)
Nasal (blocked or runny nose or sneezing)	23 (40)
Eye (irritated eyes)	13 (22)
Chest (coughing, wheezing, chest tightness)	13 (22)
Skin symptoms	13 (22)

SPT, Skin prick testing.

*One subject did not fill out the questionnaire, one subject failed to produce an acceptable lung function test, and one subject refused blood sampling (*n* = 58 for this information).

†According to questionnaire: ‘Yes’ to attacks of tightness of the chest and/or wheezing, and these symptoms occur without an airway infection, and/or these symptoms may occur during exercise.

although birds or reptiles were also common as pets (both 35%). Almost all reported having had exposure to animals from an early age, and mean exposure time for dogs was 16 years, cat 14 years, and horses and rabbits both 10 years.

Allergen and endotoxin exposure

Personal occupational aeroallergen exposure

The RUA levels were generally low, only 23% were above detection limit, whereas MUA exposure was measurable in 75% of the pet shops (Fig. 1). Levels in pet shops without rodents were mainly below detection limit. Airborne Fel d 1 was found in all pet shops.

Personal occupational endotoxin exposure

Endotoxin levels (*n* = 40) were not significantly different between pet shops with rodents and shops with only other animals and were very low in supply shops (Fig. 1).

Sedimenting aeroallergens at work and at home

Sedimenting airborne dust collected at the sales counters and in the animal rooms using petri dishes (*n* = 40) varied greatly between shops (<0.3–642 ng/m²/day for RUA,

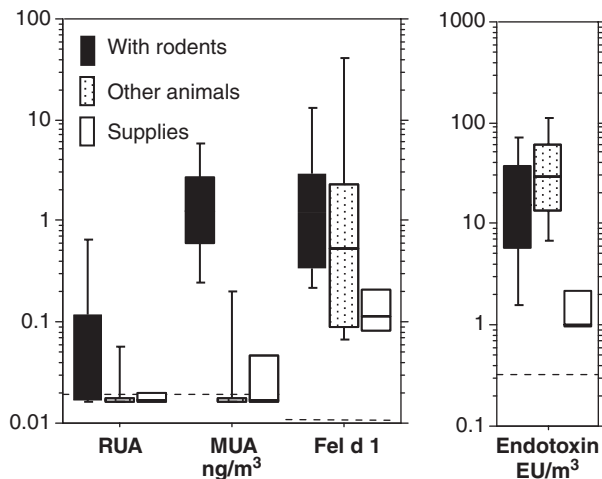


Figure 1 Airborne levels of allergens and endotoxin in pet shops selling rodents, other animals or pet supplies only. Samples were collected using person-carried pumps during work. Box plots. Detection limits are indicated with hatched lines.

<0.3–3091 ng/m²/day for MUA, and 0.5–566 ng/m²/day for Fel d 1, respectively). Levels of rodent allergen were undetectable in pet shops without rodents. In shops with rodents, rodent allergen levels were higher (Wilcoxon signed rank test) in the animal rooms than at the counters, median 54.8 vs 1.2 for RUA ($P = 0.0006$) and 550 vs 60.3 ng/m²/day for MUA ($P = 0.003$), respectively. Fel d 1 levels were instead lower in the animal rooms: 18.7 vs 37.4 ng/m²/day ($P = 0.03$).

Sedimenting dust collected in bedrooms ($n = 45$) showed higher rodent or cat allergen levels in homes with the respective animals (data not shown). There were indications of allergen transfer between shops and homes: MUA levels were a median 3.5-fold higher ($P = 0.02$) in samples from homes of nonmouse owners who worked with mice, than in homes of workers from shops without mice. The home median levels of MUA were about one-tenth of shop counter levels, while

Fel d 1 was found in shops at about one-tenth of the levels of the homes with cats.

Sensitization and symptoms

Forty-one persons worked in shops with rodents, 13 in shops without rodents, and five in pet supply shops. Atopy, defined as a positive Phadiatop test or a positive SPT to a common inhalant allergen, was found in 29%. Positive Phadiatop and SPT were highly related ($P < 0.001$), and SPT positivity was most common against dogs (17%), timothy grass (15%), and birch and cat (both 12%).

Immunoglobulin E sensitization to pet shop allergen panels was found in 13 (SPT) and 10 (serum) persons, respectively, in total 16 (27%) of pet shop workers (Table 2). The highest IgE levels were found against *Zophobas* larvae and their droppings, and against mealworm.

A majority of pet shop workers reported nasal (53%) and/or eye (34%) symptoms, and 22% reported wheezing or tightness of the chest not related to infections, indicating asthma. Wheezing ever was reported by 35%. However, only four subjects had a doctor's diagnosis of asthma. Lung function values were on average slightly lower than expected: 91.4% (SD ± 10.9) of expected for VC, 93.3% (± 11.1) for forced VC, and 94.8% (± 13.3) for FEV₁. The average ratio FEV₁/VC was normal, 101.5% (± 7.2) of expected, but 21 persons had a ratio below 80% (of which six persons were below 75%).

A third of pet shop workers (20 persons) reported having experienced allergic symptoms at work, mostly against rodents and rabbits, birds, insects and chironomids, and hay. Four subjects spontaneously mentioned strong work exposure reactions such as edema, flush, rash, and asthma attack. A further eight persons were uncertain whether symptoms were related to work (Table 1).

Risk factors in relation to sensitization and symptoms

Sensitization to the pet shop allergens and allergic symptoms at work were highly correlated, $P = 0.002$. Immunoglobulin E to pet shop allergens significantly increased the prevalence

Table 2 Results of work immunoglobulin E (IgE) sensitization tests: skin prick testing ($n = 59$) and IgE antibody (kUA/l) in serum to pet shop allergens, kU/l ($n = 58$)

Pet shop allergen panel	No. positive (%)	Pet shop allergen panel	No. positive (>0.35 kUA/l) (%)	Lowest – highest IgE antibody values
Skin prick test		IgE antibody in serum		
Rat	6 (10)	Rat urinary allergen	5 (9)	<0.1–3.9
Guinea pig	5 (8)	Mouse urinary allergen	5 (9)	<0.1–39.7
Lepidoglyphus destructor	5 (8)	Zophobas droppings	5 (9)	<0.35–212.9
Rabbit	3 (5)	Zophobas larvae	4 (7)	<0.35–143.4
Hamster	3 (5)	Mealworm (<i>Tenebrio molitor</i>)	3 (5)	<0.35–99.7
Acarus siro	3 (5)	Gerbil epithelium	2 (3)	<0.35–4.0
Budgerigar	2 (3)	Chironomid larvae	2 (3)	<0.35–9.3
Shrimp	0	Bird mix	1 (2)	<0.35–0.64

Table 3 Risk factors and symptoms at work or sensitization to work allergen panel

Risk Factors	Proportion with symptoms at work without risk factor <i>n</i> (%)	Proportion with symptoms at work with risk factor <i>n</i> (%)	Prevalence Ratio 95% CI	Proportion with sensitization to work allergens without risk factor <i>n</i> (%)	Proportion with sensitization to work allergens with risk factor <i>n</i> (%)	Prevalence Ratio 95% CI
Personal factors						
Sensitization to work allergens	9/43 (21)	11/15 (73)	3.5 (1.8–6.8)**	–	–	–
Work symptoms†	–	–	–	5/39 (13)	11/20 (55)	4.3 (1.7–11)**
Male sex	11/39 (28)	9/19 (47)	1.7 (0.8–3.3)	7/39 (18)	9/20 (45)	2.5 (1.1–5.7)*
Smoking, current	17/44 (39)	3/14 (21)	0.55 (0.19–1.6)	12/44 (27)	3/14 (21)	OR 0.79 (0.26–2.4)
Atopy (Skin prick testing and/or Phadiatop positive)	9/42 (21)	11/16 (69)	3.2 (1.6–6.2)**	2/42 (5)	14/17 (82)	OR 17 (4.4–68)***
IgE > 100 kU/l	15/50 (30)	4/7 (57)	1.9 (0.9–4.1)	8/50 (16)	7/8 (88)	OR 5.5 (2.8–11)***
Work exposure						
Work years with animals	6.5 (4.0–13)	7.5 (3.5–13)	0.64	7.0 (3.5–13)	7.0 (4.0–13)	0.85
Endotoxin (EU/m ³)	13.6 (9.5–50.8)	13.9 (9.5–39.5)	0.70	13.8 (9.5–48.4)	12.7 (3.8–29.3)	0.34
RUA (ng/m ³)	<0.02 (<0.02–0.18)	<0.02 (<0.02–0.09)	0.92	<0.02 (<0.02–0.24)	<0.02 (<0.02–<0.02)	0.33
MUA (ng/m ³)	0.84 (0.17–2.17)	0.92 (0.03–3.22)	0.98	0.84 (0.06–1.80)	1.72 (0.52–3.57)	0.11
RUA at counter (ng/m ² /day)	0.9 (<0.2–2.4)	1.7 (<0.2–3.4)	0.31	0.95 (<0.2–2.8)	1.1 (0.37–2.5)	0.71
MUA at counter (ng/m ² /day)	60.3 (9.8–238)	21.4 (9.2–79.3)	0.28	23.6 (8.6–190)	60.0 (10.3–165)	0.99

* < 0.05; ** < 0.001; *** < 0.0001. MUA, mouse urinary allergen; RUA, rat urinary allergen.

#Mann–Whitney *U*-test.†Workers who have answered 'No' (*n* = 30) or 'Don't know' (*n* = 8) to whether their symptoms were work-related are grouped as without work-related symptoms.

of work symptoms ($PR = 3.5$) and *vice versa* ($PR = 4.3$) (Table 3). Atopy strongly increased pet shop panel sensitization prevalence ($PR = 17$) and work symptoms ($PR = 3.2$). Immunoglobulin E was significantly ($P < 0.001$) higher among pet shop sensitized workers vs nonsensitized: median (25th–75th percentiles) 90 (63–304) and 16 (7–47) kU/l, respectively. IgE > 100 kU/l was also significantly related to sensitization ($PR = 5.5$), as was male sex ($PR = 2.5$). There were no correlations between allergen levels or endotoxin levels and either work symptoms or work sensitization.

Discussion

This study is the first to investigate exposure, work-related allergic sensitization and respiratory symptoms among pet shop workers. We found that a large proportion of pet shop workers reported airway symptoms at work and that about a third was IgE sensitized to allergens present in pet shops. Sensitization to pet shop allergens increased the risk (PR) of symptoms at work 3.5-fold, and work symptoms increased the risk of sensitization 4.3-fold. The strongest risk factor for sensitization to pet shop allergens was atopy ($PR = 17$), which also had an impact on work symptoms ($PR = 3.2$). Elevated IgE also increased risk of sensitization ($PR = 5.5$). The proportion of atopics (29%) was similar to that observed in Swedish blood donors (26%) (22). Although this is a cross-sectional survey, limiting the possibility to claim causality, similar results (but with lower PR s) have been found in longitudinal studies of laboratory animal workers exposed to rodents (16, 23). It is possible that some of the high correlations between positive IgE tests are caused by cross-reactivity between related allergens, such as various mite species or serum albumins (24).

The most common pet shop-sensitizing allergens were rat and MUAs along with *Zophobas*. The highest IgE levels were actually found against *Zophobas* larvae and their droppings. This large mealworm, used as reptile fodder in pet shops, and chironomids and crickets, were reported by several workers to have caused occasional strong allergic reactions.

We also found that pet shop workers may be exposed to many animal allergens both at work and at home and that allergens may be spread from work to the home and *vice versa*. The constant high exposure to organic dust or components such as endotoxin may conceivably be connected to the slightly decreased lung function found in these lifelong animal-exposed workers, similarly to farmers (25). However, the endotoxin levels were well below such measured in several other occupational environments, causing for instance organic toxic dust syndrome (26). It is possible that endotoxin or other microbial exposures have prevented more workers to develop sensitization or symptoms or conversely that the levels were mostly too low to promote tolerance. In a recent study of laboratory animal workers, we found that high rodent allergen and endotoxin exposure induces a systemic engagement with increased levels of circulating neutrophils, monocytes, and interleukin-6, unrelated to allergic sensitization [Blidberg 2010 submitted].

Although this is the largest study of pet shop work to date, the numbers do not allow sensitization and symptom analysis by shop type. Furthermore, several workers had because of work-related symptoms changed their exposure making such an analysis precarious to interpret. The fact that we did not find exposure to be related to work symptoms or sensitization may thus be a healthy worker effect, because of work adaption, with avoidance of animals, tasks or workplaces causing problems.

Both under- and overrepresentations of allergic workers are possible. Several shop owners who responded to the invitation but declined participation had one-person companies, for whom it is understandably difficult to close the shop to undergo allergy and lung function tests. Nevertheless, this study represents the first in which a large number of pet shops have been investigated, including personal exposure measurements, allergy, and lung function tests. A further strength is that the worker's exposure at home has been studied.

Although 22% of the workers reported wheezing or tightness of the chest not in connection with an infection, only four (7%) had prior to our study received a doctor's diagnosis of asthma and obtained treatment. Thus, too few with symptoms indicative of asthma have undergone allergy or lung function tests and received a diagnosis, let alone medication or preventive advice.

In conclusion, pet shop workers are exposed to a variety of allergens, which constitute a risk factor for allergic sensitization and symptoms. The findings stress the importance of improved knowledge of health risks among pet shops workers and possible allergen avoidance measures. For clinicians, it is important to remember that fodder insects such as *Zophobas*, or chironomids, may cause allergy and asthma in pet shop workers.

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Authors' contributions

AR was responsible for the project, participated in all stages and tasks, and was main author of the manuscript. MO contributed to the planning of the study was responsible for the data collection and analysis of samples from pet shops and reviewed the manuscript. MH was responsible for the data collection and analysis of samples from the workers and reviewed the manuscript. SGOJ contributed to the IgE analyses and provided critical review of the manuscript. MvH contributed to the IgE analyses and provided critical review during the project and of the manuscript.

Conflicts of interest

The authors (AR, MO, MH, SGOJ, and MvH) declare no conflicts of interest.

Supporting Information

Additional Supporting Information may be found in the online version of this article found at: <http://www.wileyonlinelibrary.com>.

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Figure S1. Pet shop worker showing Zophobas larvae sold as reptile fodder.

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