
Mite and cat allergen exposure in Brazilian public transport vehicles

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Background: Mites and pets are important sources of indoor allergens.

Objectives: To determine *Dermatophagoides pteronyssinus* (Der p 1), *Dermatophagoides farinae* (Der f 1), and *Felis domesticus* (Fel d 1) allergen levels in buses and taxis and to evaluate the predominant allergen in each vehicle type.

Methods: Mite and cat allergens were measured using enzyme-linked immunosorbent assay in dust samples collected from upholstered seats in 60 natural-ventilation buses (NVBs), 60 artificial-ventilation buses (AVBs), and 60 taxis. Thirty dust samples from AVB air-conditioning filters were also included.

Results: Levels of Der p 1 and Der f 1 were significantly higher in AVBs than in NVBs, whereas Fel d 1 levels were not significantly different between bus types. No significant differences were found in mite allergen levels in various sites in both types of buses, whereas Fel d 1 levels were significantly higher in rear and middle seats than in front seats in NVBs. Mite and cat allergen levels in taxis were significantly higher in passenger's rear seats than in driver's seats. A high proportion of dust samples from the vehicles, especially AVBs (82% for Der p 1 and 58% for Der f 1) had sensitizing levels of mite allergens, whereas more than 60% of samples from all vehicles had sensitizing levels of Fel d 1 allergen. In AVBs, samples from seats showed significantly higher levels of mite and cat allergens than those from air-conditioning filters.

Conclusions: Public transport vehicles constitute an important allergen reservoir for continuous contamination of the indoor environment.

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INTRODUCTION

Mites and pets are important sources of indoor allergens,¹ and their role in the development of allergic diseases has been recognized for many years.² Besides homes, public places such as day-care centers and schools,³ hospitals,⁴ cinemas,⁵ and public transport vehicles^{6,7} have been considered to be exposure sources of mite and pet allergens. The occurrence of allergens in these public places has been attributed mainly to passive allergen transport on clothing,^{8–12} although environmental factors, such as temperature and relative humidity, can influence the levels of mite allergens.^{13,14} The surfaces of mattresses, carpets, and vehicle seats constitute the main sites where sensitizing levels of *Dermatophagoides pteronyssinus* (Der p 1), *Dermatophagoides farinae* (Der f 1), and *Felis domesticus* (Fel d 1) allergens can be found.^{6,7,12,15} In train seats and urban buses, Partti-Pellinen et al⁶ detected significant levels of pet allergens, particularly Fel d 1.

It is widely recognized that exposure levels of 2 µg/g of dust or more of Der p 1 or Der f 1 allergens and 1 µg/g of dust or more of Fel d 1 allergens are considered risk factors for allergenic sensitization in genetically predisposed individuals.^{16,17} Thus, high levels of mite and pet allergens in public transport vehicles could represent a significant problem in sensitized individuals, especially when traveling long distances. Therefore, knowledge of allergen exposure in vehicles will allow the establishment of additional avoidance measures to prevent sensitization or manifestation of allergic respiratory symptoms in atopic patients.

The aim of this study was to determine the levels of Der p 1, Der f 1, and Fel d 1 allergens in different sites in buses and taxis and to evaluate the predominant allergen in each vehicle type.

METHODS

Public Transport Vehicles

Three bus companies from Uberlândia, Brazil, were contacted to participate in a study on allergen exposure in interstate buses, which were divided into 2 groups according to the air ventilation system: 60 buses with air-conditioning, ie, artificial-ventilation buses (AVBs), and 60 buses without air-conditioning, ie, natural-ventilation buses (NVBs). A total of 60 urban, naturally ventilated taxis in Uberlândia were also included in the present study, which was conducted between January 15, 2000, and January 14, 2002. Informed consent was obtained from the bus company managers and taxi owners.

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Dust Sampling and Allergen Extraction

Three dust samples were obtained from each bus and consisted of composite samples collected from all the seats in the following rows: (1) front seats (collected from seats 1–16), (2) middle seats (seats 17–32), and (3) rear seats (seats 33–46). In addition, 1 dust sample from the air-conditioning filter in each AVB was also collected. Dust sampling obtained from each taxi followed similar criteria: (1) driver's seat, (2) passenger's front seat, and (3) passenger's rear seat. After superficial and quick cleaning with no vacuuming of vehicles by the bus companies or taxi owners, dust samples were collected using a vacuum cleaner (1200 W; Electrolux, Manaus, Brazil) adapted with a paper filter for dust retention during approximately 3 minutes for vehicle seats (0.5–1.0 g of dust) and 1 minute for air-conditioning filters from AVBs (0.1–0.2 g of dust). All sampled seats were upholstered, and their surfaces were coated by cushion and woven fabrics. Dust samples were stored at 4° C until further allergen extraction.

Fine dust was obtained by sieving through a 300- μ m mesh screen (US Standard Sieve Series ASTM). Samples of 100 mg were extracted overnight at 4° C in 2 mL of borate-buffered saline solution (pH 8.0), and, after centrifugation at 10,000g for 10 minutes, supernatants were stored at –20° C before immunoassays.

Enzyme-Linked Immunosorbent Assay for Measuring Mite and Cat Allergen Levels

Enzyme-linked immunosorbent assays for mite (Der f 1 and Der p 1) and cat (Fel d 1) allergens were carried out as described elsewhere¹⁵ using their respective capture monoclonal antibodies: anti-Der f 1 (clone 6A8), anti-Der p 1 (5H8), or anti-Fel d 1 (6F9) and detection antibodies consisting of biotinylated monoclonal antibodies anti-group 1 *Dermatophagoides* allergens (4C1) or anti-Fel d 1 (3E4C4). After incubation with streptavidin-peroxidase (Sigma-Aldrich Corp, St. Louis, MO), the assay was developed by adding enzyme substrate (0.01 M 2,2'-azino-bis-3-ethylbenzthiazoline sulfonic acid containing 0.03% hydrogen peroxide), and the reaction was read at 405 nm. Reference standards, provided by the University of Virginia (UVA), were included in each plate to obtain control curves ranging from 0.5 to 250 ng/mL for Der f 1 (UVA 93/03 [year/lot]) and Der p 1 (UVA 93/02) and from 0.078 to 80 ng/mL for Fel d 1 (UVA 94/02). Absorbance results are expressed in micrograms per gram of dust, as previously described elsewhere.¹⁸ The highest level of each allergen found in the 3 different sites in a bus or taxi was taken as an exposure index, as described by Sopelete et al.¹⁵

Statistical Analysis

Because the allergen concentrations followed a non-Gaussian distribution, calculations were performed using nonparametric tests. Geometric means (GMs) with 95% confidence intervals (CIs) were obtained for the allergen levels, and the

differences between the means were analyzed using the Mann-Whitney *U* test. $P < .05$ was considered to be statistically significant.

RESULTS

Mite and Cat Allergen Levels in Public Transport Vehicles

Mite and cat allergens were measured in 540 dust samples from upholstered seats of 180 public transport vehicles. There were no significant differences among the 3 different sites in NVBs and AVBs for Der p 1 and Der f 1 allergens (Fig 1). However, Fel d 1 allergen levels were significantly higher in rear (GM, 0.93 μ g/g of dust; 95% CI, 0.62–1.38 μ g/g of dust) and middle (GM, 0.68 μ g/g of dust; 95% CI, 0.44–1.05 μ g/g of dust) seats than in front seats (GM, 0.39 μ g/g of dust; 95% CI, 0.26–0.57 μ g/g of dust; $P < .001$ and $P = .04$, respectively) in NVBs (Fig 1A) but not in AVBs (Fig 1B). In taxis, levels of mite and cat allergens were significantly higher in passenger's rear seats than in driver's seats ($P = .04$ for Der p 1, $P = .002$ for Der f 1, and $P < .001$ for Fel d 1; Fig 1C). In addition, statistically significant differences were also found between passenger's front seats and driver's seats ($P = .04$).

Exposure Indexes of Mite and Cat Allergens in Public Transport Vehicles

When analyzing the mean exposure indexes for each type of vehicle, it was observed that Der p 1 and Der f 1 allergen levels were significantly higher in AVBs (4.3 and 2.4 μ g/g of dust, respectively) than in NVBs (1.6 and 0.8 μ g/g of dust, respectively; $P < .001$ for both allergens) and that levels of Fel d 1 were not significantly different between the types of buses ($P = .16$; Table 1). In addition, Der p 1 was the predominant allergen in AVBs, with levels above the risk factor for sensitization (4.3 μ g/g of dust), although Der f 1 and Fel d 1 allergens were also detected at sensitizing levels (2.4 and 1.5 μ g/g of dust, respectively). In NVBs, Der p 1 and Fel d 1 were the most common allergens and were detected close to or above the threshold levels for sensitization (1.6 and 1.2 μ g/g of dust, respectively). On the other hand, Der f 1 and Fel d 1 allergens found in taxis were predominantly close to or at sensitizing levels (1.7 and 1.6 μ g/g of dust, respectively).

To evaluate the exposure indexes for Der p 1, Der f 1, and Fel d 1 allergens found in each public transport vehicle, the percentages of dust samples containing allergen levels above threshold levels for sensitization were calculated (Fig 2). Thus, Der p 1 levels of 2 μ g/g of dust or more were predominantly found in 82% of AVBs compared with 45% of NVBs and 23% of taxis ($P < .001$ for both). Also, sensitizing Der p 1 levels were significantly higher in NVBs than in taxis ($P = .01$). Sensitizing levels of Der f 1 were found in 58% of AVB and 40% of taxi samples, which were significantly higher than the 20% of samples in NVBs ($P < .001$ and $P = .02$, respectively). On the other hand, Fel d 1 levels of 1 μ g/g of dust or more were detected in more than 60% of samples collected from all types of vehicles ($P = .25$ for NVBs vs

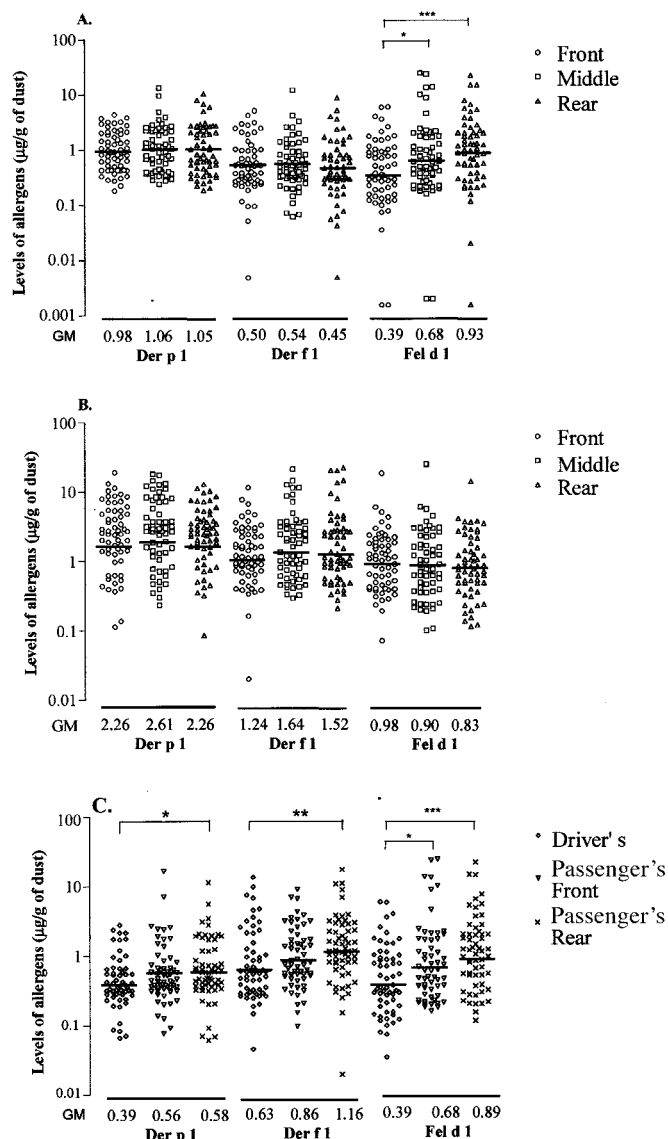


Figure 1. Levels of *Dermatophagoides pteronyssinus* (Der p 1), *Dermatophagoides farinae* (Der f 1), and *Felis domesticus* (Fel d 1) allergens in public transport vehicles. Dust samples were collected from front, middle, and rear seats in 60 natural-ventilation buses (A) and 60 artificial-ventilation buses (B) and from driver's, passenger's front, and passenger's rear seats in 60 taxis (C). Horizontal bars indicate geometric means (GMs); asterisks, $P < .05$; double asterisks, $P < .01$; and triple asterisks, $P < .001$.

AVBs; $P = .41$ for AVBs vs taxis; $P = .73$ for NVBs vs taxis).

Mite and Cat Allergen Levels in Seats and Air-Conditioning Filters of AVBs

Comparisons between levels of mite and cat allergens detected in dust samples collected from seats (analyzed as the exposure index) and air-conditioning filters in AVBs are

Table 1. Exposure Indexes for Der p 1, Der f 1, and Fel d 1 Allergens in Seats from 60 NVBs, 60 AVBs, and 60 Taxis

Type of vehicle	Allergens, $\mu\text{g/g}$ of dust*		
	Der p 1	Der f 1	Fel d 1
NVB	1.6 (1.3–2.1) ^{a†}	0.8 (0.6–1.0) ^a	1.2 (0.9–1.5) ^a
AVB	4.3 (3.4–5.4) ^b	2.4 (1.9–3.1) ^b	1.5 (1.2–1.9) ^a
Taxi	0.9 (0.7–1.1) ^c	1.7 (1.3–2.2) ^b	1.6 (1.2–2.2) ^a

Abbreviations: Der p 1, *Dermatophagoides pteronyssinus* allergen; Der f 1, *Dermatophagoides farinae* allergen; Fel d 1, *Felis domesticus* allergen; NVB, natural-ventilation bus; AVB, artificial-ventilation bus.

* Data are expressed as geometric means (95% confidence intervals), considering the highest level for each allergen (from the 3 sites) in a bus or taxi as the exposure index.

† Different letters indicate statistically significant differences between the types of vehicles, as indicated by the Mann Whitney U test ($P < .05$).

shown in Figure 3. Mean levels of Der p 1, Der f 1, and Fel d 1 were significantly higher in seats than in air-conditioning filter samples of AVBs ($P < .001$ for all allergens).

DISCUSSION

People spend more than 5% of their time inside transport vehicles,¹⁹ and allergens in public transport vehicles could represent a significant problem by inducing allergic symptoms in susceptible individuals. Mite and pet allergens can be found in such vehicles and probably are transported from place to place by adhering to clothing.¹² Several factors, such as the occupancy level, ventilation system, temperature, and relative humidity of different indoor public places or transport vehicles, can influence allergen levels.^{20–22}

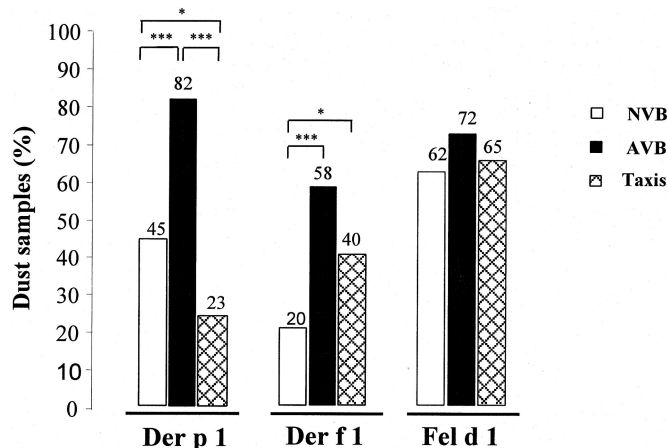


Figure 2. Percentage of dust samples, analyzed as exposure indexes, containing sensitizing levels of *Dermatophagoides pteronyssinus* (Der p 1; $\geq 2 \mu\text{g/g}$ of dust), *Dermatophagoides farinae* (Der f 1; $\geq 2 \mu\text{g/g}$ of dust), and *Felis domesticus* (Fel d 1; $\geq 1 \mu\text{g/g}$ of dust) allergens in naturally (NVBs) and artificially (AVBs) ventilated buses and taxis. Asterisks indicate $P < .05$; triple asterisks, $P < .001$.

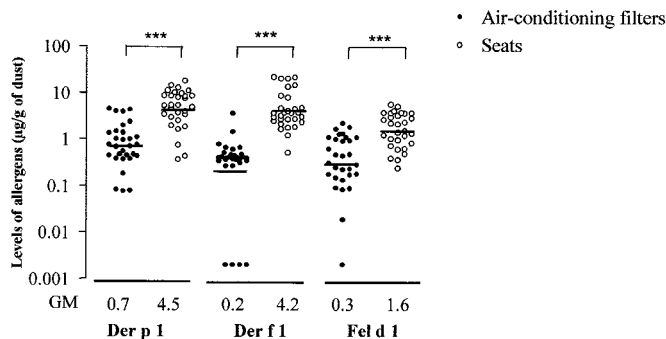


Figure 3. Levels of *Dermatophagoides pteronyssinus* (Der p 1), *Dermatophagoides farinae* (Der f 1), and *Felis domesticus* (Fel d 1) allergens in 30 dust samples collected from seats (analyzed as exposure indexes) and air-conditioning filters in artificial-ventilation buses. Horizontal bars indicate geometric means (GMs); triple asterisks, $P < .001$.

In the present study, a broad range of mite and cat allergen levels was found in different types of public transport vehicles, including levels above the threshold values that are considered risk factors for allergenic sensitization or induction of allergic respiratory symptoms. Although a superficial and quick cleaning of vehicles was done by the bus companies or taxi owners, this approach seems not to have underestimated the allergen levels. On the contrary, this is a routine procedure, and the allergen levels obtained reflect the actual allergen exposure to which the passengers are exposed at the beginning of their trip.

Buses are the principal means of public transportation in Brazil. A uniform distribution of mite allergens was found at different sites (front, middle, and rear seats) in the 2 types of buses (NVBs and AVBs) analyzed. In contrast, cat allergen levels were not equally distributed in NVBs but were detected in higher concentrations in rear and middle seats than in front seats. These data suggest that mite allergens are uniformly distributed in buses regardless of their ventilation system, natural or artificial (buses with air-conditioning). However, the higher prevalence of cat allergens in the middle to rear seats might reflect the disturbance of allergens by the vehicle movement. These allergens probably are brought in on cat owners' clothing because pets are not allowed on Brazilian public transport vehicles. In this context, Munir et al²³ reported that levels of Fel d 1 in public places can vary within a day and day to day depending on the number of people who visit these areas. Similar cat allergen levels were also found in taxis, reflecting the passive transport of cat allergen on passengers' clothing because there is a high flow of different passengers who could have a cat at home.

In Brazil, the major house dust mite is *D pteronyssinus*,²⁴ although recently *D farinae* or Der f 1 allergen was the most common in our region.^{15,25} In both types of buses, the predominant allergen was Der p 1, which was found in higher concentrations in AVBs than in NVBs, with exposure indexes above the threshold values in AVBs for allergenic sensitiza-

tion (4.3 and 1.6 µg/g of dust, respectively). The ventilation system in buses has a significant impact on house dust mite allergen occurrence. Natural but not artificial ventilation allows higher air movement and air exchange rates because people travel most of the time with the windows opened, and, consequently, the allergen concentrations in the bus are reduced. In contrast, in buses with an artificial air-conditioning system (AVBs), people always travel with the windows closed, resulting in lower air exchange rates and thus a higher concentration of mite allergens.

Higher concentrations of Der p 1 than Der f 1 were found in both types of buses. This is surprising because Der f 1 is the predominant allergen in this region, but this finding can be explained by the fact that such buses, although belonging to a company located in this region, travel long distances to different states and thus can be transporting Der p 1 allergens from other places. Previous studies on mite allergen exposure have been reported in public transport vehicles such as passenger trains in Japan⁷ and Glasgow.²⁶ The most common species was *D pteronyssinus*, which resembled that of house dust, although the density of mites was far lower and the mites have probably been transported from home via clothing and pets.²⁶ In contrast, Uehara et al⁷ found high levels of mite allergen (>10 µg per square meter or gram of dust) in upholstered commuter train seats, suggesting that train seats are mite-breeding locations in Japan.

When analyzing the mite allergen exposure index according to the threshold for sensitization or induction of allergic respiratory symptoms (≥ 2 µg/g of dust), our results demonstrated that 82% and 58% of sampled AVB seats had Der p 1 and Der f 1 levels of 2 µg/g of dust or greater, respectively. These results were significantly higher than those found in NVBs and taxis, indicating that high mite allergen concentrations sufficient to be a risk factor for sensitization and induction of symptoms are preferentially found in AVBs. In contrast, other studies have shown mite allergen levels of less than 2 µg/g of dust in seat samples from trains and buses⁶ and private cars.²⁷ The extremely low levels of mite allergens found in the latter vehicles can be ascribed to unfavorable mite-growing conditions, such as high temperature and low humidity inside the cars because of long-term closed windows in tropical climates. On the other hand, in the present study, a significant proportion of taxi seats (40%) showed sensitizing levels of Der f 1 but not Der p 1. This is likely owing to 2 factors: (1) taxis usually move around the city, where Der f 1 was found to be the most prevalent mite allergen,¹⁵ and (2) taxis are commonly stationed in shadowy places with the windows opened, thus providing more favorable conditions for mite breeding than private cars.

We found that a high proportion ($>60\%$) of sampled seats in both types of buses and taxis contained sensitizing levels of Fel d 1 (≥ 1 µg/g of dust). Cat allergens are probably deposited from clothing onto public transport vehicle seats. In support of this hypothesis, several studies^{11,23,28} have reported that Fel d 1 allergen has been detected in diverse public places where pets are not allowed. In addition to adherence to

clothing, cat allergens may be disseminated as airborne particles because of their small size ($<2.5\ \mu\text{m}$) and hence can be carried over long distances.²⁹

Regarding the mite and cat allergen levels detected in seat and air-conditioning filter samples from AVBs, the results showed that seats rather than air-conditioning filters are the main reservoirs of allergens in buses with artificial ventilation. Therefore, the higher levels of dust mite allergen detected in AVBs than in NVBs is of great interest, as is the finding that dust mite and cat allergen levels were significantly lower in air-conditioning filters from AVBs.

We conclude that upholstered seats from public transport vehicles, such as buses (artificially more than naturally ventilated) and taxis, constitute an important allergen reservoir for continuous contamination of the indoor environment, which could compromise the effects of allergen avoidance used at home. This study again demonstrates that allergens are not restricted to the home environment and that sensitizing levels of dust mite and cat allergens are, in part, a community exposure problem. Thus, additional control measures to reduce mite and pet allergen exposure should be extended to public transport vehicles because the knowledge and determination of allergen exposure in these vehicles will be useful for a global avoidance strategy, in which taxi owners and transport company managers should be aware of its importance and use. Finally, health professionals, especially allergists, should also be aware of this additional possibility of allergen exposure when considering the medical management of their mite- and cat-sensitized patients.

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