ORIGINAL ARTICLE

Airborne Food Allergen and Aeroallergen Levels in Health Care Settings: An Unaccounted for but Potentially Relevant Source of Exposure?

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Abstract

Background: Exposure to airborne allergens of biological origin is associated with the development and exacerbation of allergic asthma and rhinitis. Assessment of allergen exposure in health care facilities may improve monitoring of hygiene and surveillance of specific allergens that can cause symptoms in sensitized persons.
Objective: To assess concentrations of airborne food and aeroallergens in various health care settings in Portugal.
Methods: Dust was vacuumed from primary health care centers in Lisbon and from the emergency department, day hospital, internal medicine ward, operating room, and outpatient clinic of a university central hospital in Porto. Samples were sieved, weighed, and extracted, and concentrations of Nbos d 5, Cor a 9, Gal d 2, Ara h 3, Ara h 6, Der p 1, Fel d 1, Can f 1, Bla g 2, Alt a 1, and Phl p 5 were determined using a multiplex array for allergens (MARIA).
Results: All airborne food and aeroallergens were found in at least 1 sampled area, except for Alt a 1. Levels of Der p 1 and Fel d 1 ranged from 13.0 µg/g to 971.0 µg/g and from 7.0 µg/g to 4618.8 µg/g, respectively. Higher levels of food allergens were found in the emergency department (Nbos d 5, 16 034.0 µg/g; and Cor a 9, 10 649.5 µg/g).
Conclusions: Except for the operating room, exposure levels for dust mite and cat and dog dander in health care facilities were above the values associated with sensitization and allergic asthma or rhinitis symptoms in sensitized persons.

Key words: Airborne food allergens. Allergic disease. Health care centers. Aeroallergens. Indoor exposure.

Resumen

Antecedentes: La exposición a alérgenos en el aire de origen biológico se asocia con el desarrollo y exacerbación del asma alérgica y la rinitis. La evaluación de la exposición a los alérgenos en los centros sanitarios puede contribuir a controlar la higiene y examinar los alérgenos específicos que pueden causar síntomas en sujetos sensibilizados.
Objetivo: Evaluar la concentración de alérgenos alimentarios en interiores y en el aire en diferentes entornos de atención médica.
Métodos: Se aspiró el polvo de centros de atención primaria de salud en Lisboa, de la unidad de urgencias, hospital de día, sala de medicina interna sala de operaciones, y la clínica ambulatoria de un hospital central de la universidad de Oporto. Las muestras fueron tamizadas, pesadas, extraídas y se determinó las concentraciones de Nbos d 5, Cor a 9, Gal d 2, Ara h 3, Ara h 6, Der p 1, Fel d 1, Can f 1, Bla g 2, Alt a 1 y Phl p 5 utilizando una matriz múltiple para alérgenos (MARIA™).
Resultados: Todos los alimentos en el aire y los aeroalérgenos se encontraron al menos en un área muestreada, excepto Alt a 1. Los niveles de Der p 1 y Fel d 1 variaron de 13,0 a 971,0 µg/g y de 7,0 a 4.618,8 µg/g, respectivamente. La unidad de emergencia reveló los niveles más altos de alérgenos alimentarios, a saber, Nbos d 5 (16.034,0 µg/g) y Cor a 9 (10.649,5 µg/g).
Conclusiones: Con la excepción de la sala de operaciones, los niveles de exposición a los ácaros del polvo y a los alérgenos de gato y perro en los centros de salud fueron superiores a los valores asociados con la sensibilización y la aparición de asma alérgica o síntomas de rinitis en sujetos sensibilizados.

Palabras clave: Alérgenos de alimentos en el aire. Enfermedad alérgica. Centros de salud. Aeroalérgenos. Exposición interior.

Introduction

Allergic diseases are a major concern in developed countries, and their prevalence continues to grow worldwide [1-4]. The increasing amount of time spent indoors has been one of the most prominent changes in our lifestyle in recent decades, leading to concern over the impact of indoor air pollutants on allergic symptoms not only in homes, but also in day-care buildings, nurseries, schools, and other public places [5-7]. Although several studies have reported the health effects of both chemical and biological agents [8,9], indoor and airborne food allergens have received little attention.

Allergen exposure has been associated with the development and exacerbation of allergic asthma and rhinitis [10,11]. The World Health Organization (WHO) has proposed a Der p 1 threshold for acute asthma symptoms of 10.0 µg/g [12]. Recently, other thresholds have been defined for sensitization to Fel d 1 (1.0 µg/g and 8.0 µg/g, respectively), Bla g 2 (1.6 µg/g), and Can f 1 (10.0 µg/g) [13]. Most are considered the minimal exposure required for the induction of sensitization and allergic symptoms and are used to assess the exposure-response relationship between allergens and symptoms or exacerbations [13-17].

Residential exposure to allergens is common and high levels of allergens are found in many homes [18]. A large study in the United States showed that more than 90% of bedrooms had 3 or more detectable allergens and that over two thirds had at least 1 highly elevated allergen level [19]. Assessment of allergen exposure in the workplace has also increased, especially in environments with dominant exposures to specific allergens, such as bakeries, animal facilities, seafood-processing environments, and health care facilities [20-22]. In health care facilities, allergen levels in the environment surrounding a patient can be monitored for 3 reasons: assessment of hygiene standards; determination of the presence of specific allergens, which may be the source of allergic symptoms; and application of the information recorded to establish thresholds for allergens. Therefore, we aimed to assess airborne food and aeroallergens levels in different health care settings.

Methods

Setting and Study Design

Dust samples were collected from primary health care centers (PHCCs) and from a university central hospital as part of the ExPOSE study in July and December 2018, respectively [23]. ExPOSE is a cross-sectional study performed in 10 PHCCs in Lisbon and in 5 different areas of a university central hospital in Porto, Portugal.

At the PHCCs, samples were collected from medical offices, vaccination rooms, treatment rooms, corridors, and warehouses/cleaning rooms. At the hospital, dust samples were collected from the yellow zone of the emergency department, day hospital, internal medicine ward, 1 operating room (OR), and outpatient clinic (Table S1). These areas were representative of each building and entailed greater exposure for health workers and patients, as identified using the walkthrough survey [24]. At the PHCCs, medical offices and treatment and vaccination rooms were cleaned at least once a day after working hours. Treatment and vaccination rooms were also cleaned several times a day, especially if a procedure involving body fluids or waste was performed [24]. At the university central hospital, the operating room was cleaned frequently between procedures. The yellow zone of the emergency department had its own cleaning routines throughout the day. Every time a procedure was performed, surfaces and floors were promptly cleaned, and waste was collected. In the case of the day hospital, internal medicine ward, and outpatient clinic, surfaces and floors were cleaned after working hours during the evening. Each area had its own hygiene plan, and all cleaning was performed by an external company according to standardized and approved protocols.

The study was conducted according to the Declaration of Helsinki. The project was approved by the University and Hospital Health Ethics Committee and by the Regional Health Administration Ethics Committee.

Sample Collection and Processing

Settled dust was collected using a vacuum cleaner (HOOVER Brave BV71_BV10 A2) with a DUSTREAM collector containing a 40-µm nylon collection filter (Indoor Biotechnologies) placed on the distal end of the vacuum's extension wand. All sampling areas were vacuumed for 10 minutes (Table S2) during working hours. One settled dust sample was collected from the floor, chairs, desks, and upholstered furniture in each PHCC and hospital area (n=15). After sampling, the collection filter was removed from the collector, sealed in a polyethylene bag, and frozen at –80ºC until analysis.

Measurement of Airborne Food Allergens and Aeroallergens

Before analysis, vacuumed dust samples were sieved through a 355-µm mesh to remove unwanted particles and weighed to a maximum of 100 mg and a minimum of 20 mg (Table S3), according to the manufacturer's instructions (Indoor Biotechnologies, Inc.).

Samples were extracted in PBS-T solution (0.05% Tween 20 in phosphate-buffered saline [pH, 7.4]) at a proportion of 1 mg of dust to 0.02 mL of extraction solution. For samples weighing between 20 and 100 mg, an adjusted proportional volume of PBS-T was added. Samples were resuspended using a vortex mixer and mixed for 2 hours using a lab rocker.

MARIA 8-plex and 3-plex analysis (Indoor Biotechnologies, Inc) were performed to determine the concentration of airborne food allergens and common aeroallergens, including milk (*Bos domesticus* β-lactoglobulin [Nbos d 5]), hazelnut (*Corylus avellana* [Cor a 9]), egg (*Gallus domesticus* [Gal d 2]), peanuts (*Arachis hypogaea* [Ara h 3, Ara h 6]), mites (*Dermatophagoides pteronyssinus* [Der p 1]), cat (*Felis domesticus* [Fel d 1]), dog (*Canis familiaris* [Can f 1]), cockroach (*Blattella germanica* [Bla g 2]), molds (*Alternaria alternata* [Alt a 1]), and grass (*Phleum pratense* [Phl p 5]).

Dust extract samples were diluted at 1/10, 1/100, and 1/10 000 for MARIA 8-plex and at 1/1, 1/5, 1/20, and 1/100 for MARIA 3-plex. Allergen levels were measured in a Luminex 200 multiplex array according to the manufacturer's instructions. The array uses fluorescence-labeled beads conjugated to monoclonal antibodies specific for purified allergen molecules. A 12-point standard curve was plotted in duplicate to quantify the allergen levels. Additionally, quality controls provided with the test kit were applied. Results were expressed in nanograms per milliliter (ng/mL) and then converted to micrograms per gram (µg/g) (Table).

The lower limit of detection (LLOD) was calculated based on the lowest usable point of the standard curve for each allergen. The expected allergen concentration of this point was then multiplied by the lowest dilution factor in the assay (10 for indoor allergens and 1 for airborne food allergens). The LLOD was as follows: 12.0 µg/g for Ara h 3, Bla g 2, Can f 1, and Der p 1; 4.0 µg/g for Alt a 1, Ara h 6, and Fel d 1; 10.0 µg/g for Phl p 5; and 0.4 µg/g for Nbos d 5, Cor a 9, and Gal d 2.

Allergen concentration was determined using the median fluorescence intensity (MFI) result for each allergen and sampling area, based on the usable MFI range of the standard curve. When more than 1 value was within the usable MFI range, the geometric mean was applied for test results within 30% of the coefficient of variability, and the result corresponding to the lowest dilution was applied for test results that had increased with the dilution factor.

Results

The highest levels of milk (Nbos d 5), hazelnut (Cor a 9), and peanut (Ara h 3 and Ara h 6) were observed in the emergency department of the university central hospital (16 034.0 µg/g, 789.3 µg/g, 276.4 µg/g, and 80.5 µg/g, respectively). The highest levels for egg (Gal d 2), were observed in a PHCC and in the emergency department (13 6612.9 µg/g and 10 649.5 µg/g) (Table, Figure).

In relation to indoor allergens, dust mite (Der p 1) concentrations were higher in one of the PHCCs (971.0 µg/g), whereas in hospital areas, the highest levels were observed in the outpatient clinic (394.1 µg/g). The maximum concentrations of cat (Fel d 1) and dog (Can f 1) allergens were also found in the PHCCs (4618.8 µg/g and 2111.4 µg/g, respectively), whereas in the hospital outpatient clinic, the Fel d 1 concentration reached 1320.4 µg/g. Cockroach (Bla g 2) allergen concentrations were only observed in 2 PHCCs (98.2 µg/g and 133.9 µg/g). Levels of Phl p 5 were only detected in 6 PHCCs. All the levels corresponding to hospital areas were below the LLOD (Table, Figure).

Discussion

Our observational study yielded relevant findings. Surprisingly, except for the operating room, exposure levels of dust mite, cat, and dog allergens in health care facilities were

Table. Concentration of Airborne Food and Indoor Allergens Measured in Each Primary Health Care Center and University Central Hospital Areas (n=15)[a]

	Food allergen					Indoor allergen					
	Milk Nbos d 5	Hazelnut Cor a 9	Egg Gal d 2	Peanut Ara h 3	Peanut Ara h 6	Mite Der p 1	Cat Fel d 1	Dog Can f 1	Cockroach Bla g 2	Mold Alt a 1	Grass Phl p 5
P1	661.5	11.3	693.3	11.5	23.4	971.0	4618.8	122.0	<12.0	<4.0	<10.0
P2	733.5	5.3	5719.3	30.1	33.7	888.2	482.9	2111.4	98.2	<4.0	456.9
P3	5155.1	2.7	7815.7	22.3	26.4	277.9	968.1	296.4	<12.0	<4.0	31.7
P4	283.5	2.4	1310.3	9.0	<4.0	73.0	395.1	48.9	<12.0	<4.0	266.5
P5	528.9	2.3	246.7	<12.0	34.8	67.1	832.7	39.6	<12.0	<4.0	105.2
P6	1720.1	25.3	2911.0	77.5	30.9	140.6	352.3	673.6	<12.0	<4.0	<10.0
P7	<0.4	<0.4	<0.4	< 12.0	9.5	243.6	845.5	126.9	<12.0	<4.0	800.1
P8	2831.9	42.3	2350.1	25.7	31.8	374.0	771.5	411.9	<12.0	<4.0	817.8
P9	843.7	1.6	5699.8	32.3	67.3	301.4	352.2	135.3	133.9	<4.0	<10.0
P10	15.0	1.2	13 6612.9	16.4	8.4	119.1	305.4	34.9	<12.0	<4.0	<10.0
H1	16 034.0	789.3	10 649.5	276.4	80.5	226.6	424.1	193.6	<12.0	<4.0	<10.0
H2	939.1	1.5	1911.8	<12.0	<4.0	211.1	510.7	107.6	<12.0	<4.0	<10.0
H3	7274.9	43.2	6784.0	<12.0	15.6	107.7	248.0	41.4	<12.0	<4.0	<10.0
H4	230.4	4.6	86.9	<12.0	<4.0	13.0	7.0	<12.0	<12.0	<4.0	<10.0
H5	10 983.0	13.0	3663.1	21.1	33.5	394.1	1320.4	155.9	<12.0	<4.0	<10.0

Abbreviations: H, university central hospital; H1, yellow zone of the emergency department; H2, day hospital; H3, internal medicine ward; H4, operating room; H5, outpatient clinic; P, primary health care center.
[a]Values expressed in µg/g.

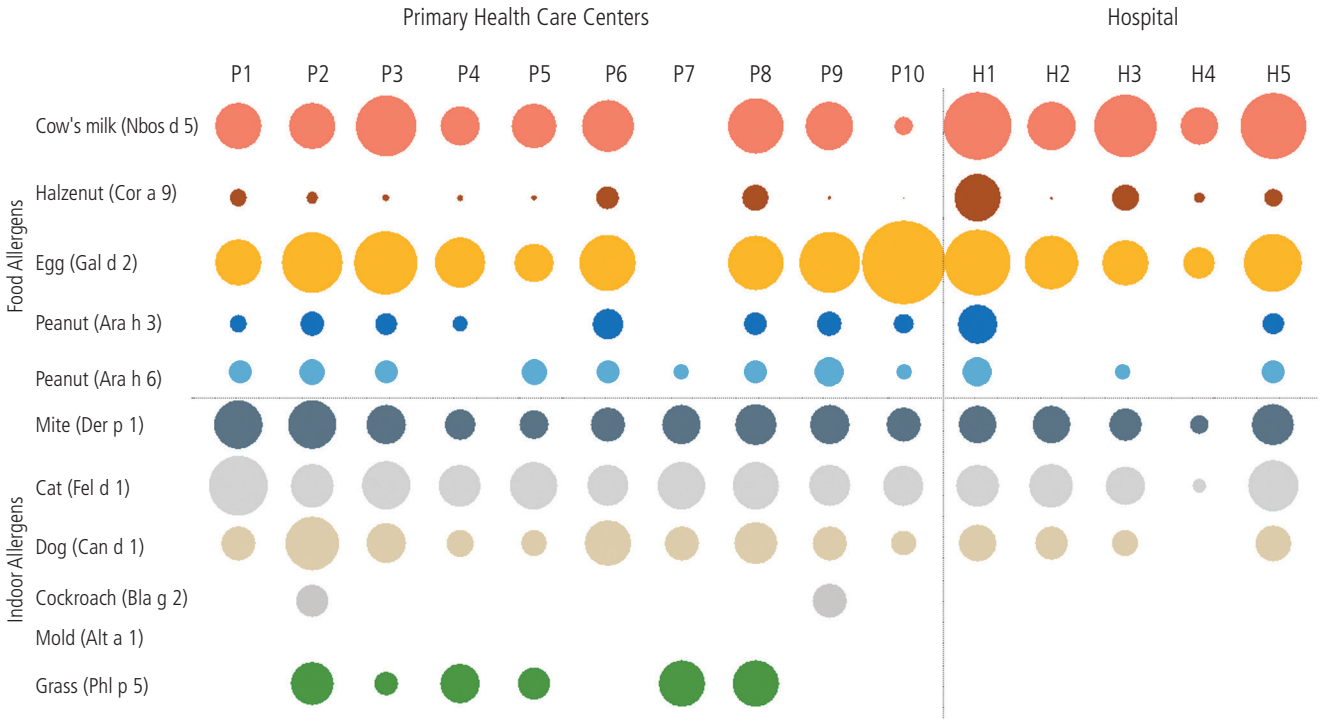

Figure. Geometric representation of the concentration of airborne food and indoor allergens measured in each healthcare setting (n=15)[a].
H indicates university central hospital; H1, yellow zone of the emergency department; H2, day hospital; H3, internal medicine ward; H4, operating room; H5, outpatient clinic; P, primary health care center.
[a]Concentrations of food and indoor allergens (in µg/g) were logarithmically transformed.

above the values associated with sensitization and occurrence of allergic asthma or rhinitis symptoms in sensitized persons [12,13]. Measurable concentrations of indoor and airborne food allergens in settled dust were found in health care areas where allergic patients are frequently observed and evaluated, as in the emergency department and in the outpatient clinic. Although exposure to airborne food allergens does not typically result in anaphylaxis, the levels detected may cause allergic symptoms, such as itchy eyes, runny nose, cough, nasal congestion, and respiratory distress [25].

Our observations are subject to a series of limitations. The cross-sectional nature of our study does not allow us to establish causal relationships. Furthermore, for operational reasons, dust samples were collected during the summer at the PHCCs, and in winter at the university central hospital; this may have influenced the concentration of pollen aeroallergens indoors, either by infiltration or through ventilation [26]. In fact, differences in pollen levels between facilities (only measurable in PHCCs) may reflect these diverse collection times. In addition, we did not evaluate the effect of the allergen concentrations on health workers' and patients' health in terms of symptoms or IgE measurements. Furthermore, collected dust weight in the operating room was below the minimum defined by the manufacturer for the analysis, and it is possible that the levels detected may have been underestimated. Still, our study has important strengths. It is the first to measure the levels of airborne food and aeroallergens in different health care settings, including PHCCs and diverse milieus within a tertiary hospital. Additionally, dust samples were collected from floors, chairs, desks, and upholstered furniture; this approach is considered a proxy for exposure [10]. In these reservoirs, particles are large in diameter and deposit instead of remaining airborne, thus improving the accuracy of allergen levels in health care areas [10].

Recent studies have shown evidence of adverse associations between aeroallergen exposure and health outcomes, even though most of them quantified levels of aeroallergens in allergic patients' homes [19,27,28]. A correlation between exposure and sensitization has been suggested [15,29-31], and it is well known that sensitization to dust mite is associated with asthma, wheeze, and bronchial hyperresponsiveness [32-34]. A study from Malaysia reported that even lower concentrations of Der p 1 (median=0.5562 µg/g) were associated with wheeze, rhinoconjunctivitis, and airway symptoms in allergic individuals [35]. Considering that health care facilities are heavily occupied by both patients and health workers, the high levels of indoor allergens may be a source of symptomatic exacerbations in susceptible persons attending the hospital or a PHCC.

In previous studies conducted in hospitals, concentrations of dust mite allergen have also been reported [21,22]. A study conducted in the northwest of England found lower allergen concentrations than ours (<10.0 µg/g) [22]. Der p 1, Fel d 1, Can f 1, and Bla g 2 were measured in dust samples collected by vacuuming upholstered chairs, carpets, and mattresses in 14 hospitals. Levels of Bla g 2 and Der p 1 were below the limits of detection, although higher concentrations of Can f 1 and Fel d 1 were found in upholstered chairs, suggesting they

may serve as a reservoir for indoor allergens [22]. Dog and cat allergen concentrations in upholstered chairs decreased with more frequent vacuum cleaning [22]. The dust mite allergen concentrations we observed were higher than those reported in Portuguese homes (median = 9.2 μg/g) [26]. Allergen levels may vary according to building characteristics and indoor activities, type of ventilation, temperature, humidity, furniture, and cleaning routines. Most of the previous studies were performed in allergic patients' homes, and these differences may be explained by selection bias resulting from more frequent cleaning of allergic persons' homes [27] and the high occupancy rate of health care settings. Indeed, occupants' behaviors (eg, pet ownership) have been associated with higher concentrations of aeroallergens [36,37]. For instance, Berge et al [38] and De Lucca et al [39] found that cat, dog, and mite allergens are brought to public areas by those who come into regular contact with them. Dispersal of allergens via clothing and the lack of uniform wearing may also explain the high concentrations of cat allergen found in our sampled areas. Iraola et al [40] reported hair and scalp as a source of mite allergens that are potentially transferred from individuals to the clinical setting. In addition, measurable levels of Bla g 2, Fel d 1, Can f 1, and Der p 1 found in health care centers may suggest that different cleaning procedures could be implemented to reduce these concentrations based on the symptom threshold. However, comparisons between our results, previous studies, and the thresholds proposed are limited by differences in the methodologies used for allergen quantification [41].

Exposure to food allergens without ingestion has been recognized in asthma and other diseases [25,42], ie, it can occur by inhalation or merely by being in the vicinity of the food [25], inducing airway reactions [43,44]. In our study, cow's milk (Nbos d 5), hazelnut (Cor a 9), and egg (Gal d 2) allergens were detected in all of the areas assessed, except in 1 PHCC. Other authors have found that eating in bed was linked to the presence of cow's milk allergen in dust in mattresses [45]. A significant increase in hen's egg protein has been detected in dust from both houses and children's beds after cooking or consumption [46]. We were not expecting to find cow's milk, hazelnut, and egg allergens inside health care facilities, since none of the vacuumed areas included eating spaces. These findings could be explained by eating habits within workplaces, such as medical offices or nurseries. A knowledge of egg allergen distribution and spread through other routes, such as saliva or hands, may be important if we are to understand these unexpected high concentrations in health care spaces, which are not physically or architecturally associated with eating areas, such as dining halls or coffee shops.

Our findings indicate that it is important to assess the health effects of and airborne food allergens and aeroallergens in health care settings, especially in places occupied by high-risk patients, such as those from the allergy clinic, and to review sensitization and symptom thresholds. In addition, sampling and analysis methodologies should be standardized for identification and management of environmental exposures and assessment of health effects. In fact, the topic of aerosolized allergic reactions has stirred enough controversy among food-allergic travelers that some airline companies have stopped serving peanuts on flights. This not only reflects the potential impact of exposure on human health, but also the need of further research on this topic. Taken together, our findings suggest that high levels of indoor and airborne food allergens can be found in very dissimilar health care settings. Therefore, further studies are needed to identify possible sources and procedures that lead to the levels recorded, to ascertain the clinical significance of allergen exposure on patients and medical personnel's health, and to implement concrete actions to reduce these concentrations.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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