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Skin Prick Testing in a Portuguese Pediatric Population: A Multicenter Cross-Sectional Study of Clinical and Allergen Sensitization Profiles

Testes Cutâneos por Picada numa População Pediátrica Portuguesa: Estudo Transversal Multicêntrico de Perfis Clínicos e de Sensibilização Alérgica

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ABSTRACT

Introduction: Allergic diseases, particularly allergic rhinitis and asthma are highly prevalent among children and adolescents and frequently associated with sensitization to inhalant allergens. However, recent data on sensitization profiles in the Portuguese pediatric population are scarce, especially regarding regional and demographic variability. In this context, we aimed to characterize the clinical and allergen sensitization profiles of children and adolescents with allergic diseases in Portugal, through a multicenter approach.

Methods: We conducted a retrospective, cross-sectional study across 14 Portuguese hospitals between January 2021 and June 2023. Children and adolescents (< 18 years) with a clinical diagnosis of allergic diseases and at least one positive skin prick test to inhalant allergens were included. Demographic, clinical, and environmental data were collected from electronic medical records. Skin prick tests followed European Academy of Allergy & Clinical Immunology recommendations. Statistical analysis was performed using IBM® SPSS® Statistics version 29.

Results: A total of 3456 patients were included (60.5% male; median age 10 years). Allergic rhinitis (78.1%) and asthma (54.5%) were the most common diagnoses and 43.1% presented with both conditions. Sensitization was most frequent to *Dermatophagoides pteronyssinus* (84.3%) and *Dermatophagoides farinae* (74.3%), followed by *Lepidoglyphus destructor* (57.8%), grass pollens (60.4%), and *Blomia tropicalis* (23.5%). Polysensitization occurred in 58.4% of patients. Sensitization patterns varied with age. Geographic differences were noted: house dust mites sensitization predominated in coastal regions, whereas sensitization to pollens, molds, and animal epithelia was more frequent inland. Migrant children (14.2%) showed lower sensitization rates to most allergens, despite a comparable disease burden.

Conclusion: To the best of our knowledge, this is the first multicenter study to describe pediatric allergen sensitization patterns in Portugal. The high rates of polysensitization and the regional variability underscore the importance of tailored diagnostic strategies. Skin prick test remains a key tool in the initial assessment of allergic diseases.

Keywords: Allergens; Child; Hypersensitivity; Portugal; Skin Tests

RESUMO

Introdução: As doenças alérgicas, em particular a rinite alérgica e a asma, são frequentes em idade pediátrica e estão muitas vezes associadas a sensibilização a alergénios inalantes. Apesar disso, dados sobre os perfis de sensibilização na população pediátrica portuguesa são escassos, sobretudo no que diz respeito à variabilidade regional e demográfica. Neste contexto, propusemo-nos caracterizar os perfis clínicos e de sensibilização a alergénios numa população pediátrica com doenças alérgicas em Portugal, através de uma abordagem multicêntrica.

Métodos: Realizou-se um estudo retrospetivo, transversal, em 14 hospitais portugueses, entre janeiro de 2021 e junho de 2023. Foram incluídas crianças e adolescentes (< 18 anos) com diagnóstico clínico de doenças alérgicas e pelo menos um teste cutâneo por picada positivo para alergénios inalantes. Os dados demográficos, clínicos e ambientais foram obtidos através dos processos clínicos eletrónicos. Os testes cutâneos por picada seguiram as recomendações da European Academy of Allergy & Clinical Immunology. A análise estatística foi efetuada através do *software* IBM® SPSS® *Statistics*, versão 29.

Resultados: Foram incluídos 3456 doentes (60,5% do sexo masculino; mediana de idade de 10 anos). As patologias mais frequentes foram a rinite alérgica (78,1%) e a asma (54,5%), com coexistência de ambas em 43,1%. A sensibilização mais frequente foi a *Dermatophagoides pteronyssinus*

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(84,3%) e *Dermatophagoides farinae* (74,3%), seguida de *Lepidoglyphus destructor* (57,8%), pólenes de gramíneas (60,4%) e *Blomia tropicalis* (23,5%). A polissensibilização foi observada em 58,4% dos casos, variando com a idade. Identificaram-se diferenças geográficas: a sensibilização a ácaros foi mais prevalente em zonas costeiras, enquanto a sensibilização a pólenes, fungos e epitélio de animais foi mais frequente em regiões do interior. As crianças imigrantes (14,2%) apresentaram taxas inferiores de sensibilização, apesar de prevalência clínica semelhante.
Conclusão: Tanto quanto é do nosso conhecimento, este é o primeiro estudo multicêntrico a descrever os perfis de sensibilização a alergénios na população pediátrica em Portugal. As elevadas taxas de polissensibilização e a variabilidade geográfica reforçam a importância de estratégias diagnósticas dirigidas. Os testes cutâneos por picada mantêm-se fundamentais na abordagem inicial das doenças alérgicas.
Palavras-chave: Alergénios; Criança; Hipersensibilidade; Portugal; Testes Cutâneos

KEY MESSAGES

- This is the first multicenter study on allergen sensitization profiles in the Portuguese pediatric population.
- Allergic rhinitis and asthma are the most common allergic diseases in this sample and frequently co-occur.
- House dust mites and grass pollens are the most common sensitizing allergens identified through skin prick testing.
- Significant geographic and demographic variations in sensitization patterns were observed.
- Skin prick testing remains a key tool in the initial assessment of allergic diseases.

INTRODUCTION

The prevalence of allergic diseases (AD) has substantially increased in recent decades, which can be associated with more sedentary lifestyles, regular practice of indoor activities, urban air pollution, tobacco consumption and exposure, and the escalating global epidemic of overweight and obesity.[1]

Among children, the most common AD are rhinitis and asthma. According to data from the International Study of Asthma and Allergies in Childhood (ISAAC), the prevalence of rhinitis and asthma in children aged 6 - 7 years is 8.5% and 11.7%, respectively, increasing to 14.6% and 14.1% in adolescents aged 13 - 14 years.[2] In Portugal, the estimated prevalence of rhinitis in pre-school children is 43.4% and the prevalence of asthma in the pediatric population is 8.4% [Cost of Asthma in Children (CASCA) study].[3,4]

Although rarely life-threatening, allergic rhinitis and asthma are associated with significant morbidity, as symptoms interfere with patients' social and academic life (usually decreasing school performance), and the economic costs are not negligible.[1,3] Therefore, the identification of specific sensitization profiles and accurate diagnosis are essential for effective management, enabling both environmental control strategies and the selection of appropriate immunotherapy, if clinically relevant.

Skin prick tests (SPT) are considered the first-line investigation for allergic sensitization. They are widely available, low-cost, and applicable to all ages.[5] These demonstrate high sensitivity and specificity (over 80% - 97% and 70% - 95%, respectively), with a good safety profile (systemic reactions occur in less than 0.1% in pediatric cases).[5] Additionally, they provide rapid results, with few contraindications, namely acute urticaria and exacerbated atopic eczema.[5,6] The main disadvantages include the limited range of available extracts and the potential interference of certain medications, as antihistamines may suppress wheal responses and topical corticosteroids applied to the test area for more than one week may reduce local skin reactivity, leading to false-negative results.[5] Therefore, SPT interpretation should be grounded in a robust understanding of diagnostic limitations and allergic pathophysiology, as described in pediatric allergology guidelines.[6]

Geographic variation in sensitization profiles is well documented and attributed to differences in climate, vegetation, and urban versus rural environments, highlighting the need for individualized avoidance measures tailored to each patient's environmental context and specific sensitization profile.[7,8] In Portugal, the last acarological map was published in 2009 and included data from both children and adults.[8] However, in recent years, Portugal has witnessed a steady rise in migrant pediatric populations, many of whom may have sensitization profiles that differ from native residents due to environmental and genetic factors. This highlights the need for updated region-specific and demographically inclusive data on allergen sensitization. Migration has been increasingly recognized as an important determinant of AD risk. A recent systematic review and meta-analysis showed that migrants often have a lower initial prevalence of asthma, rhinitis and atopic dermatitis than host populations, but this apparent protection decreases over time, with allergy prevalence converging towards that of the host country as environmental exposures change.[9] In addition, population-based data from Germany indicate that children and adolescents with a two-sided migrant background are less frequently sensitized to the most common aeroallergens than their non-migrant peers, suggesting a complex interaction between early-life environment, migration history and allergen exposure.[10]

A previous study investigated allergen sensitization patterns in a pediatric population attending a Portuguese hospital located in northern mainland Portugal.[11] Recent

multicenter and regional studies have highlighted substantial heterogeneity in aeroallergen sensitization profiles and clinical phenotypes among children across different climatic and geographical settings, particularly in Southern Europe.[12,13] The aim of the present study was to expand the previous Portuguese perspective through a multicenter approach, offering a comprehensive view of allergic sensitization profiles in different regions of the mainland in a Portuguese population.

This represents a crucial step toward improving clinical decision-making and optimizing therapeutic strategies in pediatric allergy care. It also provides an important update to the existing knowledge of the most prevalent allergen sensitizations in the pediatric population.

Specifically, this multicenter study seeks to characterize the clinical profiles and allergen sensitization patterns of children and adolescents with AD in Portugal.

METHODS

A multicenter, retrospective cross-sectional study was conducted in 14 Portuguese hospitals, which were selected by convenience. The institutions were geographically categorized according to two criteria:

1. By geographic region, based on the *Nomenclatura das Unidades Territoriais para Fins Estatísticos* (NUTS) II: 11 hospitals in the North, 1 in the Centre, 1 in Oeste e Vale do Tejo and 1 in the Alentejo.
2. By location type: 11 coastal and 3 inland hospitals.

Participants

The inclusion criteria were: (1) children and adolescents under 18 years of age; (2) follow-up in the pediatric allergology or pediatric pulmonology clinic; (3) clinical diagnosis of an AD (asthma, allergic rhinitis, atopic dermatitis and/or conjunctivitis), based on a compatible medical history and physical examination; (4) positive SPT performed between January 2021 and June 2023.

To avoid duplicate entries, each patient was included only once in the dataset. In cases where a participant underwent more than one SPT during the study period, the most recent test was considered for analysis.

Operational definitions and group definitions

Clinical diagnoses were retrieved from the electronic medical records as recorded by the attending pediatrician and were considered to be in line with contemporaneous guideline-based practice. Asthma was defined according to the international Global Initiative for Asthma (GINA) guidelines, requiring a compatible clinical history (episodic respiratory symptoms such as wheeze, dyspnea or cough), objective evidence of variable airflow limitation when available, and/or a prior physician diagnosis of asthma. Allergic rhinitis was defined according to Allergic Rhinitis and Its Impact on Asthma (ARIA) criteria, requiring nasal symptoms (rhinorrhea, nasal obstruction, sneezing or nasal pruritus) for more than one hour on most days, with or without ocular symptoms, together with a prior diagnosis by an allergist or pediatrician. Atopic dermatitis was defined according to the United Kingdom Working Party refinement of the Hanifin & Rajka criteria, requiring chronic or relapsing eczema with typical age-dependent distribution and pruritus. For the purposes of analysis, patients were classified into mutually exclusive groups according to the diagnoses documented in their electronic medical records.

Ethical considerations

The study was approved by the Ethics Committee of Unidade Local de Saúde Santo António/Instituto de Ciências Biomédicas Abel Salazar [reference 2023.168(140-DEFI/132-CE)].

Data collection

Clinical and demographic data were obtained from clinical records through a retrospective review of electronic medical records by the Pediatric Allergology or Pediatric Pulmonology clinic team of each hospital, including age at testing, sex, place of residence, migratory status, AD profile, environmental exposures (presence of humidity, tobacco smoke exposure, and domestic animals), and family history of atopy (with specification when available). All data were anonymized to ensure full patient confidentiality and privacy, in compliance with applicable ethical standards and data protection regulations applicable to each hospital involved in the study.

Skin prick tests

Skin prick tests were commercialized by two pharmaceutical companies (LETI® and Roxall®) and the results were analyzed together, with no specification of the pharmaceutical company at the time of data collection. The tests were performed according to the European Academy of Allergy & Clinical Immunology (EAACI) recommendations, considering a mean papule diameter ≥ 3 mm compared to the negative control, assessed after 15 minutes, as a positive SPT. The panel of allergens tested included house dust and storage mites, animal epithelia, pollens (grasses, trees and other plants), and molds. Monosensitization was defined as a positive SPT to aeroallergens from a single allergen family, whereas polysensitization was defined as positive SPT to aeroallergens from two or more different allergen families.

Statistical analysis

Descriptive, univariate and multivariable analysis were

conducted using IBM® SPSS® Statistics, version 29. Categorical variables were summarized as frequencies and percentages and compared using the Chi-square test or Fisher's exact test, as appropriate. Continuous variables were summarized as means and standard deviations or medians and interquartile ranges. Multivariable associations between covariates and the study outcomes were examined using logistic regression models. A *p*-value < 0.05 was considered statistically significant.

RESULTS

General sample characteristics

A total of 3456 children and adolescents with positive SPT, performed between January 2021 and June 2023, were included in the analysis. Of these, 60.5% were male and 39.5% were female. The median age at the time of testing was 10 years [interquartile range (IQR) = 6], with the majority (66.6%) falling within the 6 - 9 and 10 - 13-year age groups. Other sample characteristics are summarized in Table 1.

Regarding geographical distribution based on the NUTS II division, 85.4% of patients were from the North, 8.1% from Oeste e Vale do Tejo, 4.9% from the Centre, and 1.6% from the Alentejo. In terms of hospital location, 87.2% were followed in coastal institutions. A total of 14.2% were migrants, most commonly from Brazil and Switzerland. These patients were predominantly followed in coastal hospitals ($p < 0.001$).

Exposure to potential environmental risk factors was frequently reported: 55.0% had domestic animals, 33.3% had documented exposure to tobacco smoke, and 28.1% were exposed to household dampness. A family history of atopy was reported in 63.4% of cases, most commonly involving the mother (30.0%) or both parents (24.4%).

Clinical profile

The most frequent AD identified among participants were allergic rhinitis (78.1%) and asthma (54.5%), followed by allergic conjunctivitis (21.2%) and atopic dermatitis (18.6%). Notably, 43.1% presented with coexisting asthma and rhinitis, 19.0% and 9.3% had isolated rhinitis and isolated asthma, respectively (Table 1). Rhinitis was the most prevalent allergic condition across all age groups, showing a progressive increase with age, followed by asthma. Isolated asthma showed a decreasing trend after the age of 10 years (Fig. 1).

Allergen sensitization profile

The overall sensitization profile is summarized in Fig. 2. Sensitization to house dust mites was almost universal, with 90.5% of patients sensitized to at least one mite species. The most frequent sensitizations were to *Dermatophagoides pteronyssinus* (84.3%) and *Dermatophagoides farinae* (74.3%), followed by *Lepidoglyphus destructor* (57.8%) and *Blomia tropicalis* (23.5%). Sensitization to *Acarus siro* was less frequent (1.3%). Overall, 74.3% were sensitized to two or more mite species.

Among pollens, the most prevalent sensitizations were to grass pollens (60.4%), including wild (51.2%) and cultivated species (34.6%), as well as *Olea europaea* (16.8%), *Platanus acerifolia* (9.2%) and *Parietaria judaica* (7.7%).

Regarding animal epithelia, sensitization was observed in 35.5% of patients, with 28.3% sensitized to cat epithelia and 21.2% to dog epithelia. Concerning fungal allergens, sensitization to *Alternaria alternata* and *Aspergillus fumigatus* were reported in 8.9% and 2.7%, respectively.

Overall, 58.4% of the sample presented polysensitization. Among monosensitized patients (41.6%), the most common pattern was sensitization to house dust mites (84.8%), followed by grass pollen (11.8%). Monosensitized patients were significantly younger than polysensitized patients ($p < 0.001$).

The mean number of sensitizations per patient was 3.52 (standard deviation = 1.87), with a median of 3.0 (IQR = 3). The four most frequent allergen sensitization combinations were: (1) *Dermatophagoides pteronyssinus* + *Dermatophagoides farinae* + *Lepidoglyphus destructor* (12.4%); (2) *Dermatophagoides pteronyssinus* + *Dermatophagoides farinae* (9.9%); (3) *Dermatophagoides pteronyssinus* + *Lepidoglyphus destructor* (3.2%); (4) *Dermatophagoides pteronyssinus* + *Dermatophagoides farinae* + *Lepidoglyphus destructor* + wild grass pollen (3.15%). All remaining combinations occurred in less than 3% of the patients.

A positive SPT to only one allergen was observed in 12.3% of the patients. Among these, the most common sensitizing allergen was *Dermatophagoides pteronyssinus* (44.5%), followed by wild grass pollen (17.4%), and *Lepidoglyphus destructor* (14.6%).

Sensitization profiles varied across age groups, with younger children showing a predominance of indoor allergen sensitization such as house dust mites, while older children and adolescents exhibited broader sensitization patterns, with a progressive increase in sensitization to other allergen sources. Patients with isolated rhinitis showed higher rates of sensitization to cultivated grass pollens ($p = 0.013$) and *Olea europaea* ($p = 0.04$). Regarding isolated asthma, these patients had higher rates of sensitization to *Acarus siro* ($p = 0.004$), and less sensitization to wild and cultivated grass pollen ($p < 0.001$).

Regional distribution and geographic patterns

Distinct patterns emerged when comparing AD prevalence and sensitization profiles between coastal and inland regions (Table 2), as well as between migrant and

Table 1 – Summary of demographic, environmental and clinical characteristics of the study population, n = 3456*

Variable	n (%)**
Sex	
Male	2091 (60.5)
Female	1365 (39.5)
Age, years (median, IQR)	10 (6)
Age category	
0 - 5 years	486 (14.1)
6 - 9 years	1221 (35.3)
10 - 13 years	1082 (31.3)
14 - 18 years	667 (19.3)
Region	
North	2950 (85.4)
Center	170 (4.9)
Oeste e Vale do Tejo	281 (8.1)
Alentejo	55 (1.6)
Location	
Coastal	3015 (87.2)
Inland	441 (12.8)
Migratory status (n = 2958)	
Migrants	421 (14.2)
Brazil	124 (29.5)
Switzerland	27 (6.4)
France	17 (4.0)
Angola	11 (2.6)
Venezuela	11 (2.6)
Spain	7 (1.7)
United Kingdom	5 (1.2)
Luxembourg	5 (1.2)
Other countries	214 (50.8)
Exposure status	
Domestic animals (n = 2674)	1472 (55.0)
Tobacco smoke (n = 2595)	865 (33.3)
Household dampness (n = 2355)	662 (28.1)
Family history of atopy	2191 (63.4)
Family history of atopy – specification (n = 2191)	
Mother	657 (30.0)
Father	461 (21.0)
Both parents	535 (24.4)
Siblings	288 (13.1)
Not specified	250 (7.2)
Allergic diseases	
Rhinitis (n = 3413)	2666 (78.1)
Asthma (n = 3357)	1831 (54.5)
Conjunctivitis (n = 3329)	705 (21.2)
Atopic dermatitis (n = 3416)	635 (18.6)
Asthma + rhinitis (n = 3343)	1441 (43.1)
Isolated asthma (n = 3296)	305 (9.3)
Isolated rhinitis (n = 3296)	626 (19.0)

IQR: interquartile range
*: Sample size n = 3456 unless otherwise specified
**: Results n (%) unless otherwise specified

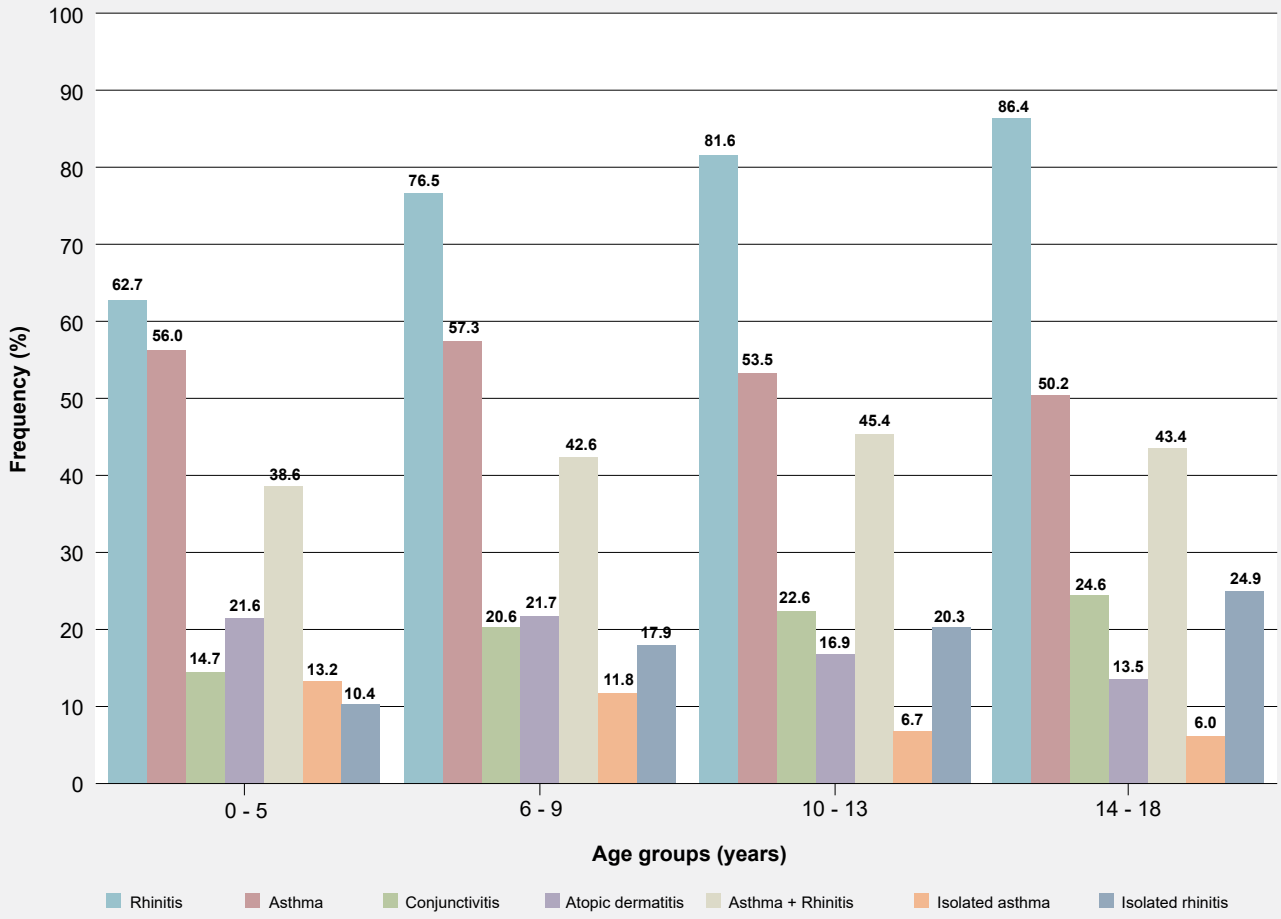

Figure 1 – Distribution of allergic diseases by age group, expressed as relative frequencies

non-migrant patients (Table 3).

Patients from coastal regions presented a higher prevalence of isolated asthma ($p = 0.002$) and combined asthma and rhinitis diagnoses ($p < 0.001$), while those from inland regions showed comparatively higher frequencies of isolated rhinitis ($p = 0.030$).

Sensitization to *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* was more common in patients followed in coastal hospitals ($p < 0.001$), whereas unadjusted comparisons regarding sensitization to grass pollen, *Parietaria judaica*, *Platanus acerifolia*, *Olea europaea*, animal epithelia and molds occurred more frequently in the inland group ($p < 0.001$). Sensitization to *Lepidoglyphus destructor* and *Blomia tropicalis* did not vary between these regions.

Regarding migratory status, migrant patients exhibited lower sensitization rates to several allergens in unadjusted comparisons, namely less sensitization to *Dermatophagoides farinae*, *Blomia tropicalis,* animal epithelia, grass pollen, *Parietaria judaica, Platanus acerifolia, Olea europaea* and molds ($p < 0.001$). The distribution of AD was similar, except for isolated asthma ($p = 0.027$), more common in non-migrant patients.

Multivariable analysis

To examine independent predictors of sensitization patterns, as well as asthma diagnosis, four logistic regression models (A, B, C and D) were estimated (Table 4). All models showed statistically significant improvement over the null model ($\Delta\chi^2$, $p < 0.001$), with Nagelkerke R^2 ranging from 0.031 to 0.092.

In Model A (sensitization to at least one house dust mite species), only a few variables remained significant after adjustment. Children followed in inland hospitals had markedly lower odds of house dust mite sensitization than those in coastal hospitals [OR (95% CI) = 0.26 (0.18 - 0.37), $p < 0.001$]. Other sociodemographic and environmental variables did not show independent associations.

Model B (monosensitization *versus* polysensitization)

showed that each additional year of age decreased the odds of being monosensitized by about 7% [OR (95% CI) = 0.93 (0.91 - 0.96), $p < 0.001$]. Monosensitization was less frequent among children followed in inland hospitals [OR (95% CI) = 0.70 (0.53 - 0.93), $p = 0.013$], indicating that polysensitization was relatively more common in the inland group.

In Model C (grass pollen sensitization), older age was independently associated with higher odds of sensitization [OR (95% CI) = 1.06 (1.03 - 1.09) per year, $p < 0.001$]. Grass pollen sensitization was also more likely in non-migrant children [OR (95% CI) = 1.78 (1.26 - 2.54), $p = 0.001$].

Model D examined factors associated with asthma diagnosis and included sensitization variables. Children followed in inland hospitals had roughly half the odds of having asthma compared with those from coastal hospitals [OR (95% CI) = 0.44 (0.30 - 0.65), $p < 0.001$]. No exposure to tobacco smoke was associated with lower odds of asthma [OR (95% CI) = 0.64 (0.48 - 0.84), $p = 0.002$]. Sensitization to house dust mites and animal epithelia were both independently associated with higher odds of asthma [OR (95% CI) = 1.81 (1.22 - 2.68), p = 0.003, and OR (95% CI) = 1.44 (1.08 - 1.92), $p = 0.012$, respectively]. Age was not independently associated with asthma after adjustment for other variables.

DISCUSSION

To our knowledge, this is the first multicenter study conducted in Portugal to comprehensively characterize allergen sensitization profiles in the pediatric population across different geographic and demographic contexts. The large sample size and broad territorial coverage provide an updated overview of the current patterns of AD and sensitization, which are essential for clinical management and public health strategies.

The high prevalence of allergic rhinitis (78.1%) and asthma (54.5%) observed in our cohort aligns with international findings and confirms the significant burden of AD in Portuguese children and adolescents.[2] The results also corroborate national data, which had already identified high rates of rhinitis and asthma in this population.[3,4] The higher estimates observed in our sample are likely due to its clinical nature, as it comprised children and adolescents followed in a hospital setting for AD.

The frequency of coexisting asthma and rhinitis (43.1%) in our sample highlights the clinical relevance of the atopic march, whereby initial sensitization, typically to indoor allergens, may precede the development of more complex allergic phenotypes.[14]

The age-related trends observed, namely, the increase in rhinitis prevalence with age and the decline in isolated

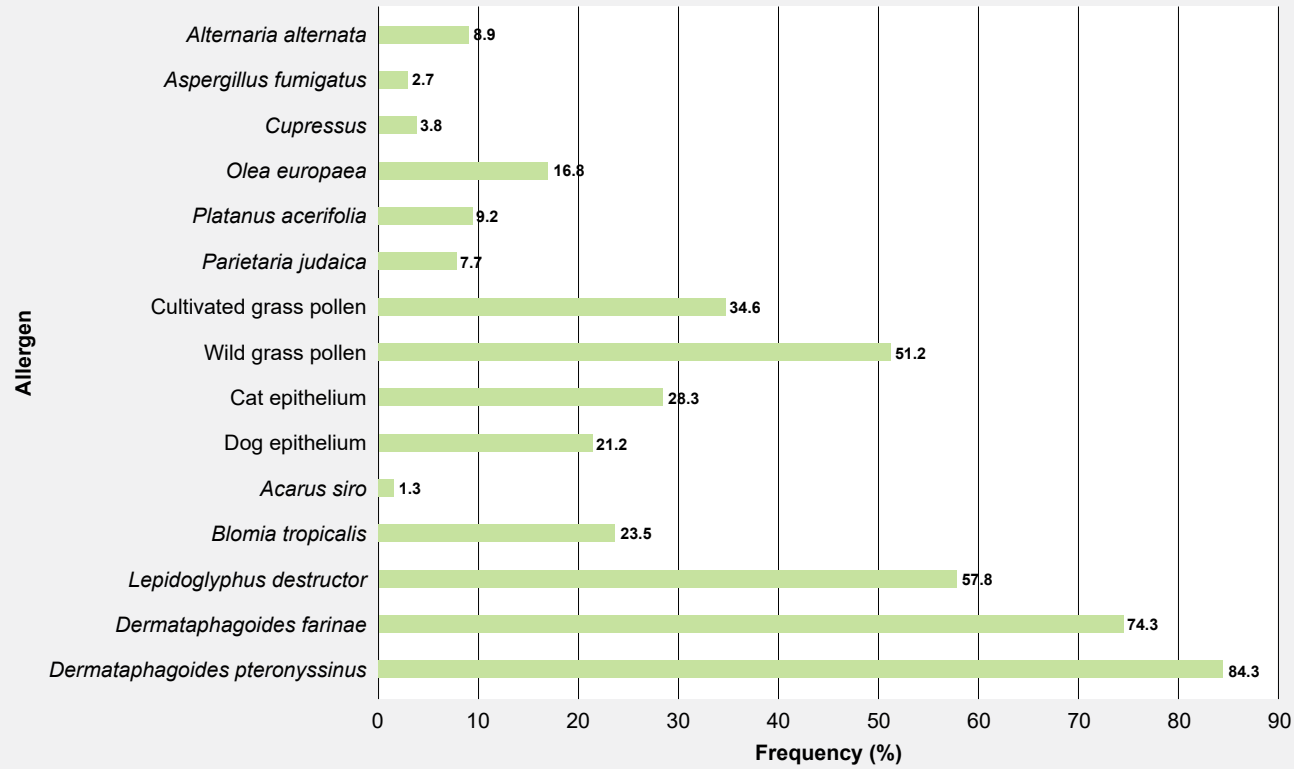

Figure 2 – Distribution of sensitization to individual allergens, expressed as relative frequencies

Table 2 – Distribution of allergic diseases and sensitization profile according to geographic location

Variable	Coastal (%)	Inland (%)	*p*-value
Allergic diseases			
Rhinitis (n = 3413)	76.6	88.4	**< 0.001**
Asthma (n = 3357)	56.3	42.7	**< 0.001**
Conjunctivitis (n = 3329)	18.3	39.8	**< 0.001**
Atopic dermatitis (n = 3416)	17.5	26.2	**< 0.001**
Asthma + rhinitis (n = 3343)	44.4	34.8	**< 0.001**
Isolated asthma (n = 3296)	9.9	5.2	**0.002**
Isolated rhinitis (n = 3296)	18.4	22.8	**0.030**
Sensitization profile			
Dermatophagoides pteronyssinus (n = 3304)	85.6	74.1	**< 0.001**
Dermatophagoides farinae (n = 3164)	75.3	67.2	**< 0.001**
Lepidoglyphus destructor (n = 3105)	58.3	53.7	0.114
Blomia tropicalis (n = 852)	23.5	21.4	0.795
Acarus siro (n = 523)	1.0	1.4	**0.013**
Dog epithelia (n = 2879)	19.0	39.8	**< 0.001**
Cat epithelia (n = 2887)	27.7	33.7	**0.030**
Wild grass pollen (n = 3001)	48.6	71.3	**< 0.001**
Cultivated grass pollen (n = 2122)	29.7	63.5	**< 0.001**
Parietaria judaica (n = 2431)	6.6	18.0	**< 0.001**
Platanus acerifolia (n = 2026)	7.4	31.0	**< 0.001**
Olea europaea (n = 2611)	13.0	48.4	**< 0.001**
Cupressus (n = 1585)	3.9	2.2	0.577
Aspergillus fumigatus (n = 1768)	2.4	5.1	**0.029**
Alternaria alternata (n = 2652)	7.6	21.0	**< 0.001**

asthma after 10 years, support the hypothesis that allergic manifestations evolve over time, reinforcing the need for longitudinal monitoring. Given that allergic rhinitis is a known risk factor for the later development or persistence of asthma, early identification of sensitization and symptom control is vital to prevent progression. This is further supported by evidence of a bidirectional interaction between upper and lower airway inflammation.[15]

Regarding allergen sensitization, house dust mites remain the dominant sensitizers in this population. *Dermatophagoides pteronyssinus* (84.3%) and *Dermatophagoides farinae* (74.3%) led the sensitization profile, supporting their central role in routine diagnostic panels. Sensitization to storage mites was also frequent, with *Lepidoglyphus destructor* identified in 57.8% of patients. This may reflect environmental changes or improved detection and highlights the need to include storage mites in routine panels. The proportion of patients sensitized to *Dermatophagoides farinae* was higher than that of *Lepidoglyphus destructor*, in accordance with previous regional reports.[16] *Blomia tropicalis*, although more prevalent in tropical and subtropical regions, was also detected in nearly one-quarter of the sample, confirming its emerging relevance in southern Europe.[17] Considering that our study was conducted mainly in the northern part of the country, these findings may also be influenced by changing climatic conditions.

The observed sensitization to pollens reflects the diversity of Portuguese flora and aligns with previous aerobiological studies demonstrating regional differences in pollen prevalence across the country.[17] Sensitization to grass pollens, both wild and cultivated, was particularly prevalent, especially among older children, which may mirror increased outdoor exposure and seasonal allergen load. Sensitization to tree pollens such as *Olea europaea*, *Platanus acerifolia*, and *Parietaria judaica* also varied regionally, highlighting the influence of local vegetation and climatic conditions.[17-19]

A geographic gradient was observed in our study, with patients from coastal areas presenting higher rates of sensitization to *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*, and those from inland regions showing greater sensitization to pollens, animal epithelia, and molds, although the latter findings are based on unadjusted observations. These patterns are likely influenced by environmental and housing differences, levels of humidity, and biodiversity, and reinforce the need for region-specific diagnostic strategies.[17,19]

Table 3 – Distribution of allergic diseases and sensitization profile according to migratory status

Variable	Migrants (%)	Non-migrants (%)	*p*-value
Allergic diseases			
Rhinitis (n = 2915)	82.5	83.2	0.718
Asthma (n = 2859)	57.1	55.7	0.607
Conjunctivitis (n = 2831)	27.2	24.5	0.277
Atopic dermatitis (n = 2918)	21.9	19.8	0.351
Asthma + rhinitis (n = 2845)	48.2	42.4	0.069
Isolated asthma (n = 2798)	7.0	10.9	**0.027**
Isolated rhinitis (n = 2798)	18.5	22.6	0.090
Sensitization profile			
Dermatophagoides pteronyssinus (n = 2806)	86.5	85.0	0.421
Dermatophagoides farinae (n = 2667)	60.2	76.5	**< 0.001**
Lepidoglyphus destructor (n = 2610)	54.0	58.9	0.071
Blomia tropicalis (n = 852)	11.6	29.2	**< 0.001**
Acarus siro (n = 523)	0.9	1.7	0.704
Dog epithelia (n = 2391)	13.5	23.0	**< 0.001**
Cat epithelia (n = 2398)	18.5	29.1	**< 0.001**
Wild grass pollen (n = 2504)	32.9	54.1	**< 0.001**
Cultivated grass pollen (n = 1842)	22.7	38.2	**< 0.001**
Parietaria judaica (n = 1940)	2.8	8.1	**< 0.001**
Platanus acerifolia (n = 1545)	2.7	10.3	**< 0.001**
Olea europaea (n = 2122)	7.4	19.3	**< 0.001**
Cupressus (n = 1102)	0.4	3.3	**0.007**
Aspergillus fumigatus (n = 1278)	0.0	2.3	**0.001**
Alternaria alternata (n = 2160)	2.8	9.6	**< 0.001**

The analysis of sensitization profiles in migrant children is particularly relevant given the rising migration flows into Portugal, and our study encompassed migrant patients from diverse countries of origin. In unadjusted comparisons, while the clinical prevalence of AD was similar between migrants and non-migrants, sensitization profiles differed, with migrant children showing lower sensitization rates to several common Portuguese allergens. However, in adjusted analyses, migratory status was not an independent predictor of sensitization to at least one house dust mite (Model A), not supporting a generally lower house dust mite sensitization rate among migrant children. These patterns may reflect prior exposures in their countries of origin, genetic background, or mismatches in testing panels. Moreover, previous international cohort studies demonstrate that sensitization rates and allergen patterns vary with migrant origin.[10,20] This underlines the importance of considering migratory history in allergology assessment, as current SPT panels may not fully capture relevant sensitizations in this population.

Given the high rates of polysensitization (58.4%), identifying specific allergens is critical to guide environmental control and allergen-specific immunotherapy (AIT). In pediatric patients, AIT has been shown to reduce symptom severity, improve quality of life, and potentially modify the course of AD.[21,22] Although molecular diagnostic tools are increasingly available and may provide more precise identification of clinically relevant components, their accessibility may be limited. In this context, SPT continues to be a first-line, cost-effective, rapid, and informative approach in daily clinical practice.[5,6]

Importantly, our multivariable analysis that included both sensitization patterns and asthma diagnosis corroborated these clinical associations. In the asthma diagnosis model, sensitization to house dust mites and to animal epithelia remained independently associated with asthma after adjustment for age, sex, location, migratory status, environmental exposures, and other allergen families. These findings confirm the central role of indoor allergen sensitization in pediatric asthma. Additionally, exposure to tobacco smoke emerged as an independent factor associated with asthma in our study. This aligns with the established epidemiological evidence linking secondhand smoke exposure to pediatric asthma risk and supports reinforcing smoking avoidance policies in households of allergic children.[23,24]

Table 3 – Multivariable logistic regression models for sensitization patterns and asthma diagnosis.

Predictor	Model A		Model B		Model C		Model D	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age (years)	0.994 (0.95 - 1.04)	0.779	0.932 (0.91 - 0.96)	< 0.001	1.057 (1.03 - 1.09)	< 0.001	0.969 (0.93 - 1.00)	0.095
Inland hospital	0.255 (0.18 - 0.37)	< 0.001	0.697 (0.53 - 0.93)	0.013	1.184 (0.86 - 1.63)	0.302	0.444 (0.30 - 0.65)	< 0.001
Female sex	1.122 (0.81 - 1.55)	0.486	1.092 (0.91 - 1.32)	0.354	0.830 (0.66 - 1.04)	0.103	0.822 (0.63 - 1.07)	0.142
Non-migrant	0.535 (0.28 - 1.04)	0.066	0.908 (0.68 - 1.22)	0.518	1.784 (1.26 - 2.54)	0.001	0.686 (0.44 - 1.07)	0.097
No tobacco smoke	0.613 (0.42 - 0.90)	0.012	0.995 (0.81 - 1.22)	0.958	1.185 (0.93 - 1.51)	0.166	0.637 (0.48 - 0.84)	0.002
No household dampness	0.722 (0.49 - 1.06)	0.098	1.073 (0.87 - 1.33)	0.510	1.152 (0.90 - 1.48)	0.267	1.034 (0.77 - 1.38)	0.820
No domestic animals	1.224 (0.89 - 1.69)	0.218	1.031 (0.86 - 1.24)	0.751	1.428 (1.14 - 1.79)	0.002	1.116 (0.86 - 1.45)	0.414
No family history of atopy	1.033 (0.73 - 1.46)	0.855	1.274 (1.05 - 1.55)	0.016	0.811 (0.64 - 1.03)	0.086	0.803 (0.61 - 1.07)	0.128
Sensitized to grass pollens							0.746 (0.57 - 0.98)	0.038
Sensitized to ≥ 1 house dust mite species							1.808 (1.22 - 2.68)	0.003
Sensitized to animal epithelia							1.441 (1.08 - 1.92)	0.012
Sensitized to molds							0.684 (0.42 - 1.12)	0.131
Sensitized to other plants							0.798 (0.50 - 1.26)	0.334
Sensitized to tree pollens							1.433 (0.95 - 2.15)	0.084

OR: odds ratio; CI: confidence interval
All models showed statistically significant improvement over the null model ($\Delta\chi^2$, $p < 0.001$), with Nagelkerke R^2 ranging from 0.031 to 0.092.
Model A outcome: sensitization to at least one house dust mite species.
Model B outcome: monosensitization.
Model C outcome: sensitization to grass pollens.
Model D outcome: asthma diagnosis.

This study has some limitations, which should be carefully considered when interpreting the findings. First, its retrospective design may have led to missing or incomplete data in clinical records, particularly regarding environmental exposures and family history. Second, several comparisons were based on unadjusted analyses and should be interpreted as descriptive, since residual confounding cannot be excluded. Third, there was no standardization of all allergen extracts used across hospitals, and some (e.g., *Blomia tropicalis*, *Aspergillus fumigatus*, *Acarus siro*, and cultivated grass pollen) may present higher prevalence rates. Fourth, most of the participating hospitals were in coastal (87.2%) and northern (85.4%) regions of Portugal, which may reduce the generalizability of the findings. Fifth, information regarding the manufacturer of the SPT extracts was not consistently recorded in electronic medical records, and in many cases the company was not specified. Therefore, this information could not be systematically collected, and it was not possible to reliably stratify the results according to the commercial brand. Sixth, the study included only patients with positive SPT, which introduces selection bias. As a result, our findings are not generalizable to the general pediatric population. Seventh, molecular diagnostic techniques were not analyzed in this study, limiting our ability to distinguish genuine primary sensitization from cross-reactive patterns.

Future studies should include longitudinal follow-up of sensitized children, and integration of molecular diagnostic techniques to refine allergen profiles. They should also be designed with standardized, prospective data collection that allows robust multivariable statistical modelling. It is also necessary to expand the scope of investigation to other regions of Portugal, particularly the South and inland areas. Comparative studies with other Mediterranean countries may also help contextualize our findings and improve cross-border allergy management strategies.

CONCLUSION

This multicenter study provides a comprehensive overview of allergen sensitization profiles in a large pediatric population across Portugal, highlighting significant regional and demographic variations. The predominance of sensitization to house dust mites and grass pollens, the high frequency of polysensitization, and the distinct profiles observed in migrant children emphasize the importance of tailored diagnostic and therapeutic strategies in pediatric allergy care. Given the progressive nature of AD and the role of early sensitization in disease development, SPT remains a fundamental tool in guiding clinical decisions, including the timely initiation of AIT. These findings underscore the need for continued surveillance of allergen exposure patterns, particularly in the context of changing environments and population dynamics. Future research should address prospective data collection and molecular confirmation of sensitization and explore longitudinal outcomes to better understand the natural history and modifiability of AD in childhood.

PREVIOUS AWARDS AND PRESENTATIONS

"Skin prick testing in a Portuguese paediatric population – a multicentric study" – Poster viewing and discussion on EAACI PAAM Hybrid 2023, Porto, Portugal.

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AUTHOR CONTRIBUTIONS

MLF: Study conceptualization and design, data collection, interpretation and statistical analysis, drafting and critical review of the manuscript.

MM: Study conceptualization and design, data collection, interpretation and statistical analysis, critical review of the manuscript.

ARA, ST: Study conceptualization and design, data collection, critical review of the manuscript.

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All authors approved the final version to be published.

PROTECTION OF HUMANS AND ANIMALS

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the Helsinki Declaration of the World Medical Association updated in October 2024.

DATA CONFIDENTIALITY

The authors declare having followed the protocols in use at their working center regarding patients' data publication.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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