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Aeroallergen Sensitization in Adult Allergic Respiratory Disease: Insights from the Middle Black Sea Region of Türkiye

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Research Article

Keywords: Aeroallergen, allergic rhinitis, asthma, skin prick test, pollen, house dust mites, Türkiye

Posted Date: August 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10646188/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Aeroallergen sensitization is influenced by local environmental and climatic conditions, resulting in considerable geographic variation in allergic respiratory diseases. Understanding regional sensitization patterns is essential for guiding diagnosis, allergen avoidance, and allergen immunotherapy. However, contemporary data from the humid Black Sea coastal region of Türkiye are limited. This study aimed to describe aeroallergen sensitization patterns in adults with allergic rhinitis (AR) and asthma and to explore their relationship with clinical phenotype and asthma severity.

Methods

This retrospective cross-sectional study included 754 adults diagnosed with AR and/or asthma who underwent skin prick testing at a tertiary allergy clinic between January 2023 and October 2024. Sensitization profiles were analysed according to demographic characteristics, disease phenotype, and asthma severity. Multivariable multinomial logistic regression analysis was performed to evaluate the association between major aeroallergen sensitization groups and asthma severity, with mild asthma as the reference category and adjustment for age and sex.

Results

Overall, 377 patients (50.0%) were sensitized to at least one aeroallergen, and 53.8% of sensitized individuals showed polysensitization. Among the 377 sensitized patients, pollen was the most common allergen group (60.5%), followed by house dust mites (50.9%), animal dander (44.6%), molds (24.9%), latex (21.0%), and cockroach (18.3%). Among individual allergens, *Dermatophagoides pteronyssinus* (35.3%) and *Dermatophagoides farinae* (28.6%) were the predominant sensitizers. Cockroach sensitization was significantly more frequent in patients with concomitant AR and asthma than in those with isolated AR. In contrast, sensitization to house dust mites was more common in patients with mild asthma than in those with severe disease (71.4% vs. 37.2%, $p = 0.02$). In multivariable multinomial logistic regression analysis adjusted for age and sex, severe asthma was associated with lower odds of HDMS sensitization than mild asthma (OR 0.29, 95% CI 0.11–0.81; p = 0.02).

Conclusions

Adults with allergic respiratory disease living in the Black Sea coastal region of Türkiye demonstrate a distinct aeroallergen sensitization profile characterised by frequent house dust mites sensitization, extensive pollen co-sensitization, and a high prevalence of polysensitization. The observed association between house dust mites sensitization and milder asthma highlights the heterogeneity of asthma

phenotypes in routine clinical practice. These findings support the development of region-specific diagnostic allergen panels and may help guide more individualized approaches to allergy diagnosis and management.

Introduction

Over the last twenty years, allergic rhinitis (AR) has risen to prominence as a major global health challenge, affecting up to 40% of the population and imposing a considerable burden on both quality of life and healthcare resources. Allergic rhinitis involves chronic IgE-mediated inflammation of the nasal mucosa following exposure to common aeroallergens, such as pollen, dust mites, moulds, and animal dander (1). Evidence suggests that individuals with allergic rhinitis (AR) are at greater risk of subsequently developing asthma (2, 3). Aeroallergens are key drivers in the development of these conditions; consequently, the identification of clinically relevant allergens is fundamental to establishing effective treatment and prevention strategies (1–3).

Skin prick testing (SPT) is a widely used, reliable, rapid, affordable, and minimally invasive method for identifying IgE-mediated sensitization to specific allergens in patients with atopic conditions, including allergic rhinitis, asthma, food allergy, and atopic dermatitis. By identifying allergens that are clinically relevant to a patient's symptoms, SPT improves diagnostic precision and supports personalised management strategies, including allergen avoidance and allergen immunotherapy (4).

The patterns of sensitization can vary by region due to environmental, climatic, and lifestyle factors, making local data essential for effective allergy care. In this context, understanding the regional distribution of allergen sensitization through SPT is particularly important in guiding clinicians and public health policies (5).

Türkiye's geographic position between Europe and Asia, bordered by the Marmara, Black, and Mediterranean Seas, creates substantial regional variation in climate and vegetation. The prevalence of AR in Türkiye has been reported to range from 1.6% to 27.7% in adults and from 2.9% to 39.9% in children (6). This wide variation likely reflects differences in study populations, age groups, geographic and climatic characteristics, sampling strategies, and the diagnostic criteria used to define allergic rhinitis. According to a recent asthma registry study, residents of the Marmara, Black Sea, and Aegean regions demonstrate higher rates of allergic asthma than those in other regions, with house dust mites (HDMS) identified as the leading allergen in the Black Sea region.

The Marmara and Black Sea regions of northern Türkiye are characterised by temperate climatic conditions and higher humidity compared with the Aegean and Mediterranean coastal areas.

Ordu, a city located in the Middle Black Sea region of Türkiye, represents a distinct geographical and climatic area that may influence the prevalence and characteristics of allergic respiratory diseases. The city has a humid subtropical climate with high annual precipitation and dense vegetation, particularly hazelnut plantations, which dominate the local economy and landscape. These environmental conditions

may contribute to a unique aeroallergen profile, including pollens from hazelnut trees, grasses, and other regional flora, as well as mold spores promoted by high humidity (8). Unlike western provinces, few studies have investigated allergen sensitization patterns in the Black Sea region. Therefore, this study aimed to characterise aeroallergen sensitization patterns in adults with AR and/or asthma in the Middle Black Sea region of Türkiye, to examine their clinical associations, and to interpret the observed sensitization profile in the context of the region's distinctive environmental and climatic characteristics.

Materials and Methods

Study Design

This retrospective cross-sectional study evaluated SPT results from the Department of Allergy and Immunology at Ordu University Training and Research Hospital between January 2023 and October 2024. Data were obtained from the hospital's electronic medical records. The study was approved by the Clinical Research Ethics Committee of Ordu University (date: 24 October 2024; approval number: 2024/53).

Study Population

Medical records from 754 adult patients who underwent SPT and had a diagnosis of rhinitis and/or asthma were included in the analysis. Demographic characteristics, including age and sex, and clinical indications for testing were recorded. AR was diagnosed based on clinical history and symptoms according to the Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines (1). Asthma was diagnosed according to the Global Initiative for Asthma (GINA) 2026 recommendations, based on a compatible clinical history and objective evidence of variable expiratory airflow limitation. Variable airflow limitation was confirmed by bronchodilator responsiveness, defined as an increase in FEV_1 of ≥ 12% and ≥ 200 mL following inhalation of 400 µg salbutamol, or by excessive average daily diurnal peak expiratory flow variability (> 10%) over a two-week period. Asthma severity was classified according to the level of treatment required to achieve disease control, as defined by GINA: mild asthma corresponded to treatment Steps 1–2, moderate asthma to Steps 3–4, and severe asthma to Step 5. (9).

Skin prick tests

Skin prick testing was performed on the volar aspect of both forearms using standardised commercial allergen extracts (Diater, Barcelona, Spain) and single-use lancets. This panel consisted of 18 aeroallergens: grass mix, weeds mix, *Artemisia*, trees mix, hazel tree, birch tree, olive, cat dander, dog dander, sheep dander, latex, *Dermatophagoides pteronyssinus, Dermatophagoides farinae, Acarus siro, Aspergillus, Penicillium, Alternaria*, and cockroach. Skin prick testing (SPT) was conducted according to international guidelines on the volar aspect of both forearms using lancets and standardised allergens applied by the same trained nurse, with histamine hydrochloride (10 mg/mL) and 0.9% saline used as

positive and negative controls, respectively. The wheal diameter was measured after 20 minutes and reported in millimetres. A wheal size ≥ 3 mm larger than the negative control was taken as a positive result in SPT. SPT was performed once per patient as part of the routine clinical assessment and was not routinely repeated.

Statistical Analysis

Data were analysed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA). Categorical variables were compared using chi-square tests. Continuous variables were compared using independent-samples t-tests or Mann–Whitney U tests, as appropriate. Multivariable multinomial logistic regression analysis was performed to evaluate the association between asthma severity and major aeroallergen sensitization groups, with mild asthma as the reference category; age and sex were included as covariates. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). A p-value < 0.05 was considered statistically significant.

Results

Study population

A total of 754 patients were enrolled in the study, comprising 563 females and 191 males. The mean age of the study population was 38 years (range, 18–88 years). The largest proportion of patients (n = 308, 40.8%) belonged to the 30–49-year age group (Table 1). Sensitization to at least one of the 18 aeroallergen extracts tested was identified in 377 patients (50.0%) of the 754 included patients. Among sensitised individuals, 248 (65.7%) had allergic rhinitis (AR) without asthma, whereas 129 (34.3%) had concomitant AR and asthma (Table 1).

Table 1
Distribution of all the patients and the patients with positive and negative SPTs according to age, sex, and diagnosis.

		Positive SPT		Negative SPT		Total		P-value
		n	%	n	%	n	%	
Sex	Female	266	70.6	297	78.8	563	74.7	**0.009***
	Male	111	29.4	80	21.2	191	25.3	
	Total	377	100	377	100	754	100	
Age	Mean ± SD (min-max)	36.09 ± 13.88 (18–88)		39.93 ± 15.04 (18–81)		38.01 ± 14.59 (18–88)		**0.000***
Age groups	18–29 years	152	40.3	125	33.2	277	36.7	**0.002***
	30–49 years	160	42.4	148	39.3	308	40.8	
	50 + years	65	17.2	104	27.6	169	22.4	
Diagnosis	Rhinitis alone	376	99.7	371	98.4	747	99.1	0.161
	Asthma alone	1	0.3	6	1.6	7	0.9	
	Rhinitis and asthma	129*	34.2	135	35.8	264*	35.0	
Severity of asthma*	Mild	21	17.9	12	10.1	33	14.0	0.203
	Moderate	53	45.3	62	52.1	115	48.7	
	Severe	43	36.8	45	37.8	88	37.3	

*Severity classification was unavailable for 12 SPT-positive and 16 SPT-negative asthma patients; these individuals were therefore excluded from the asthma severity subgroup analysis

Aeroallergen Sensitization Profile

All allergen prevalence percentages presented in this section were calculated among patients sensitized to at least one aeroallergen (n = 377), unless otherwise stated. Allergen groups and individual allergens were not mutually exclusive; patients sensitised to more than one allergen could therefore be represented in multiple categories. According to allergen groups, pollen was the most commonly identified aeroallergen group, with 228 patients (60.5%) showing a positive reaction to at least one type of pollen, including grass, tree, hazel, weed, olive, birch, or *Artemisia*. This was followed by HDMS (50.9%), animal dander (44.6%), molds (24.9%), latex (21.0%), and cockroach (18.3%) (Fig. 1).

The most common specific aeroallergens identified by SPT were mites (*D. pteronyssinus*, 35.3%; *D. farinae*, 28.6%), followed by birch pollen (26.5%), cat dander (24.7%), grass pollen (23.1%), tree pollen

(22.5%), dog dander (22.3%), weed pollen (21.2%), *Artemisia* (21.0%), latex (21.0%), *Acarus siro* (20.2%), hazel tree pollen (20.2%), sheep dander (18.6%), cockroach (18.3%), *Penicillium* (14.9%), *Alternaria* (14.3%), *Aspergillus* (11.7%), and olive pollen (5.3%) (Fig. 2).

Sex-Specific Patterns of Aeroallergen Sensitization

Males had a significantly higher rate of grass pollen sensitization than females ($p = 0.002$). No significant sex-related differences were observed for the remaining allergens.

Allergen Sensitization According to Age Groups

Patients were categorised into three age groups (18–29, 30–49, and ≥ 50 years). Dog dander sensitization differed significantly across age groups, with the highest prevalence observed in patients aged ≥ 50 years (30.8%) compared with those aged 18–29 years (16.4%) ($p = 0.047$).

Common Allergen Sensitization in Patients with Asthma and/or Allergic Rhinitis

Cockroach sensitization was significantly more frequent in patients with both AR and asthma than in those with AR alone ($p < 0.05$). No statistically significant differences were observed for the other tested allergens between patients with and without asthma ($p > 0.05$).

Common Allergen Sensitization According to Asthma Severity

Asthma severity was significantly associated with sensitization to tree pollen, *D. farinae*, and the HDMS allergen group. Tree pollen sensitization was lower in patients with severe asthma (9.3%) than in those with moderate asthma. HDMS sensitization was more frequent in patients with mild asthma than in those with severe asthma (71.4% vs. 37.2%, $p = 0.02$). Sensitization to *D. farinae* was also higher in patients with moderate asthma than in those with severe asthma (41.5% vs. 14.0%, $p = 0.013$). Pollen, animal dander, molds, latex, and cockroach allergen groups were not significantly associated with asthma severity ($p > 0.05$), whereas the HDMS allergen group was significantly associated with asthma severity ($p < 0.05$).

In multivariable multinomial logistic regression analysis adjusted for age and sex, severe asthma was associated with lower odds of HDM sensitization than mild asthma (OR 0.29; 95% CI 0.11–0.81; $p = 0.02$). Increasing age was also associated with severe compared with mild asthma (OR 1.05 per year; 95% CI 1.01–1.08; $p = 0.01$) (Table 2). No statistically significant associations were observed for HDM sensitization in moderate compared with mild asthma, or for the other allergen groups or sex.

Table 2
Multivariable multinomial logistic regression analysis of factors associated with asthma severity

Comparison	Variable / Allergen	p	OR	95% CI (Lower)	95% CI (Upper)
Moderate vs. Mild	Age (years)	0.08	1.03	1.00	1.06
	Sex (Male)	0.17	0.50	0.19	1.33
	Dust	0.07	0.42	0.17	1.08
	Pollen	0.47	0.67	0.22	2.00
	Animal dander	0.65	1.31	0.40	4.23
	Molds	0.61	0.70	0.18	2.71
	Latex	0.17	3.06	0.61	15.22
	Cockroach	0.69	0.76	0.21	2.82
Severe vs. Mild	Age (years)	**0.01***	**1.05**	1.01	1.08
	Sex (Male)	0.23	0.54	0.19	1.49
	Dust	**0.02***	**0.29**	0.11	0.81
	Pollen	0.82	0.87	0.28	2.69
	Animal dander	0.67	1.31	0.38	4.46
	Molds	0.81	1.19	0.30	4.71
	Latex	0.96	1.05	0.18	6.10
	Cockroach	0.59	0.68	0.16	2.81

Discussion

This study provides a contemporary characterisation of aeroallergen sensitization among adults with allergic respiratory disease in Ordu and contributes clinical data from a comparatively understudied area of the Middle Black Sea region of Türkiye. By examining sensitization patterns in relation to clinical phenotype and asthma severity, the study offers region-specific evidence from a geographically and climatically distinct population. *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* were the most frequently identified individual aeroallergens. An exploratory association was observed between HDM sensitization and asthma severity, with sensitization occurring more frequently among patients with mild than severe asthma. This finding should, however, be interpreted cautiously in view of the relatively small numbers within the asthma-severity subgroups and the wide confidence interval around the adjusted estimate. At the allergen-group level, pollen was the most frequently identified category, while birch was the most commonly detected individual pollen allergen. Taken together, these findings provide contemporary insight into aeroallergen sensitization patterns in an adult tertiary-care population

from the Middle Black Sea region and may help inform regionally appropriate approaches to allergy assessment.

Ordu is characterised by a humid subtropical climate with high atmospheric moisture and year-round precipitation. This persistently humid environment may play an important role in shaping local aeroallergen exposure, as house dust mites require high humidity levels for survival and proliferation (10, 11). Studies conducted in the Black Sea region, including Ordu, have demonstrated a high prevalence of *Dermatophagoides* species, which are strongly associated with allergic diseases (10–13). In our cohort, HDMS sensitization, particularly to *D. pteronyssinus* and *D. farinae*, was one of the most prominent findings. This result is consistent with previous studies from the Black Sea region and other areas of Türkiye, where HDMS has been reported as a leading allergen among adults with asthma and allergic rhinitis (14–19).

Similar patterns have been reported internationally in countries with warm, humid climates across Asia, the Middle East, Europe, and South America, where HDMS sensitization dominates the aeroallergen profile (20–27).

A key finding of our study is the clinical significance of weed pollens, which reflects a wider global trend associated with climate change and urbanization. Rising atmospheric carbon dioxide levels and higher temperatures have lengthened pollen seasons and allowed highly allergenic plants to spread to new geographical areas. In the Black Sea region, ragweed (*Ambrosia artemisiifolia*) is rapidly becoming a major seasonal allergen. Recent findings from the neighbouring province of Samsun show that ragweed is now one of the leading causes of AR and is strongly associated with asthma development (19). This pattern is not unique to Türkiye. Aerobiological studies across Europe and the Mediterranean, including reports on the spread of *Cupressus* species in Ankara and southern Europe, demonstrate that climate change is reshaping aeroallergen distribution and creating new patterns of allergic sensitization in regions where these allergens were previously uncommon (28–31).

Beyond geographic variability, the relationship between aeroallergen sensitization and asthma severity is complex and requires careful evaluation. In our cohort, HDM sensitization was more frequently observed among patients with mild asthma (71.4%) than among those with severe asthma (37.2%). Sensitization to *Dermatophagoides farinae* was also significantly higher among those with moderate asthma (41.5%) than among those with severe asthma (14%). To address potential confounding by age and sex, multivariable analysis showed that severe asthma remained associated with lower odds of HDM sensitization than mild asthma. Given the relatively small subgroup sizes and the absence of correction for multiple comparisons, this finding should be interpreted cautiously and regarded as hypothesis-generating rather than evidence of a protective effect. Larger prospective studies are required to confirm this association and to clarify the relationship between allergic sensitization and asthma severity. This inverse association is consistent with the growing body of evidence suggesting that severe asthma phenotypes are often driven by non-atopic or type 2-low inflammatory pathways rather than the traditional IgE-mediated pathway. Several studies have also shown that atopy and aeroallergen

sensitization are not reliable predictors of asthma severity, particularly in severe asthma cases that present in adulthood, where non-allergic phenotypes tend to be more prevalent (32–35).

At the same time, our findings, along with those of previous national and international studies, emphasize the important role of indoor allergens in lower airway disease. We found that sensitization to cockroach allergens was significantly more common in patients with both AR and asthma than in patients with AR alone. Evidence from other Turkish provinces, such as Şanlıurfa and Batman, corroborates this finding by identifying indoor allergens, particularly HDMS and cockroaches, as the primary triggers in asthmatic patients (17, 36). These findings highlight the strong link between indoor allergens and lower airway dysfunction and bronchial hyperreactivity, regardless of regional climate differences. Furthermore, large-scale analyses from China indicate that HDMS sensitization rates are intrinsically higher in lower respiratory diseases compared to purely epidermal allergies, highlighting the airway epithelium's vulnerability (26). Polysensitization, observed in 53.8% of our sensitized individuals, remains a global hallmark of concurrent AR and asthma, often correlating with more persistent symptoms and poorer quality of life.

Study limitations and clinical implications

Several limitations of this study should be acknowledged. First, the retrospective and single-center design may limit the external validity and generalizability of the findings to populations from different geographic or climatic regions. Second, recruitment from a tertiary referral allergy centre introduces the possibility of selection bias, as patients referred for specialist assessment are more likely to have persistent, complex, or clinically suspected allergic disease. Accordingly, the sensitization frequencies observed in this cohort may overestimate those in the general population and should not be interpreted as population prevalence estimates. Third, aeroallergen sensitization was assessed exclusively by SPT, without confirmation by serum-specific IgE or component-resolved diagnostics. As the diagnostic performance of SPT varies according to the allergen tested, extract characteristics, and testing conditions, some degree of misclassification of sensitization status cannot be excluded. The magnitude of this potential bias could not be quantified in the present retrospective dataset because an independent reference measure of sensitization was not systematically available. Accordingly, the reported sensitization frequencies should be interpreted as SPT-defined sensitization rather than absolute estimates of allergen-specific sensitization. Furthermore, potentially relevant factors such as environmental allergen exposure, air pollution, seasonal variation, housing conditions, and socioeconomic status were not systematically evaluated. In addition, the relatively small numbers within some asthma-severity subgroups reduced the precision of the severity analyses, as reflected by the wide confidence interval for the association between HDM sensitization and mild asthma; this finding should therefore be considered exploratory and requires confirmation in larger cohorts. Finally, the cross-sectional nature of the study limits the ability to establish causal relationships between aeroallergen sensitization patterns and asthma severity. Prospective multicenter studies incorporating environmental and molecular data are warranted to further validate and expand upon these findings.

Future perspectives

Further prospective, multicentre studies involving larger patient populations are needed to better understand regional aeroallergen sensitization patterns and their clinical implications. Incorporating environmental and climatic parameters, such as humidity, temperature, air pollution, and seasonal pollen exposure, may help clarify how local conditions influence allergic sensitization and disease severity.

Longitudinal follow-up studies could also provide valuable insight into the relationship between allergen exposure, sensitization, and the progression of allergic respiratory diseases, particularly asthma. In addition, the use of molecular allergy diagnostics may improve the identification of clinically relevant sensitizations and cross-reactivity patterns, allowing for a more individualized approach to patient management.

Given the observed association between HDM sensitization and asthma severity, future studies with larger, prospectively characterised cohorts should further investigate whether sensitization patterns contribute to distinct asthma phenotypes. Ultimately, establishing regional aeroallergen profiles may contribute to earlier diagnosis, more personalized treatment approaches, and improved long-term outcomes in patients with allergic respiratory diseases.

Conclusion

In conclusion, the aeroallergen sensitization profile observed in Ordu reflects the complex interaction between local environmental conditions and broader climate-related changes. The high frequency of HDMS sensitization in this humid coastal region, together with the increasing relevance of allergenic weed pollens, supports the need for an adaptive approach to allergy diagnosis and management. The differing associations between allergens and asthma severity also highlight the heterogeneity of allergic airway disease and the importance of precision medicine. Region-specific aeroallergen testing panels may improve diagnostic accuracy, guide environmental control measures, and optimise allergen immunotherapy strategies for patients with allergic respiratory diseases.

Abbreviations

AR
Allergic rhinitis
GINA
Global Initiative for Asthma
HDMS
House dust mites
SPT
Skin prick test
FEV_1

Forced expiratory volume in one second
FVC
Forced vital capacity
OR
Odds ratio
CI
Confidence interval

Declarations

Ethics approval and consent to participate

The Clinical Research Ethics Committee of Ordu University approved this study (Decision No: 2024/53; Date: 24 October 2024).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Clinical trial number

Not applicable

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contribution

FEG conceived and designed the study, collected and analyzed the data, interpreted the results, and drafted the manuscript. SK contributed to the study design, data interpretation, critically revised the manuscript for important intellectual content, and supervised the study. Both authors read and approved the final manuscript.

Acknowledgements

The authors thank all participants who took part in this study and the staff of the Adult Allergy Outpatient Clinic at Ordu University Training and Research Hospital for their assistance with data collection.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Figures

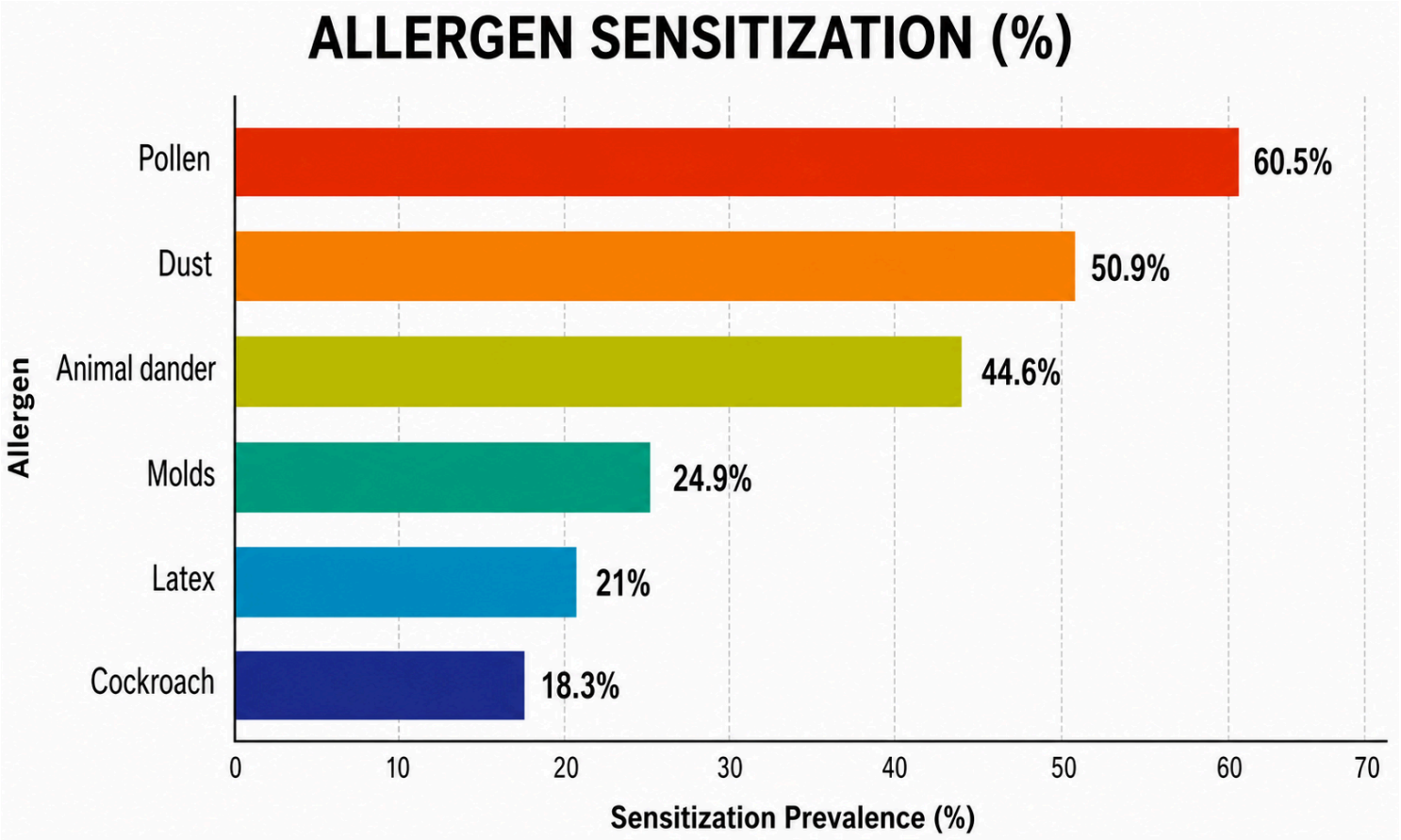


Figure 1

Distribution of sensitization to major aeroallergen categories among sensitized adult patients.

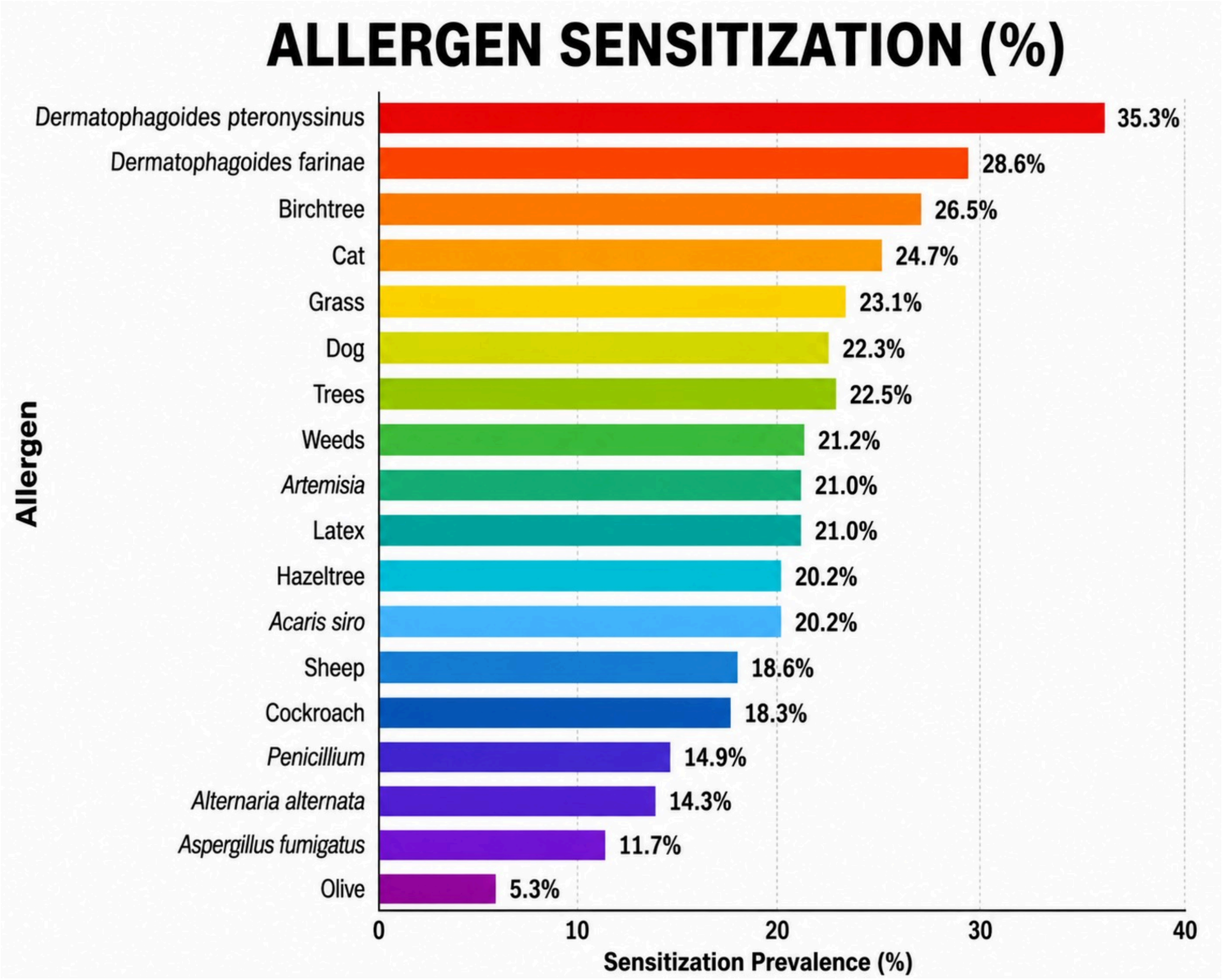


Figure 2

Prevalence of sensitization to individual aeroallergens among sensitized adult patients.