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Age-related patterns of allergen sensitization and clinical phenotypes in adults with rhinitis

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MAIN POINTS

- Allergen sensitization among adults with rhinitis is characterized by a dynamic, age-dependent pattern, with sensitization rates declining with advancing age.
- Pollen and pet dander predominate among young adults, whereas mite sensitization persists and intensifies among middle-aged and older adults.
- The coexistence of asthma and urticaria becomes more frequent with advancing age and is often associated with sensitization to mites.
- Nearly one-third of sensitized adults exhibit complex polysensitization across multiple allergen groups, underscoring the heterogeneity of allergic disease.
- These findings highlight the importance of age-adapted diagnostic, preventive, and therapeutic strategies in adult allergic rhinitis.

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ABSTRACT

Aim: Allergic rhinitis (AR) is a common chronic condition that frequently coexists with asthma or urticaria. Allergen sensitization patterns vary by geography, environmental exposure, and age; however, data on adult and elderly populations remain limited. Understanding age-related sensitization trends is essential for optimizing diagnosis, prevention, and allergen immunotherapy (AIT) strategies.

Materials and Methods: This retrospective study included 1,982 adults diagnosed with rhinitis, drawn from 7,000 patients who underwent skin-prick testing at a tertiary allergy clinic in Türkiye. Patients were categorized by age as young (18–39 years), middle-aged (40–64 years), or elderly (≥65 years), and further classified according to clinical presentation as rhinitis alone, rhinitis with asthma, rhinitis with urticaria, or rhinitis with both asthma and urticaria. Polysensitization was defined as sensitization to ≥2 allergens, and complex polysensitization as sensitization across distinct allergen groups.

Results: Overall, 58.5% (n=1160) of patients demonstrated sensitization, with rates declining with age (62.0%, 52.7%, and 29.5%, respectively; p<.001). Among sensitized patients, 53.4% showed monosensitization and 46.6% showed polysensitization, of whom 63.3% exhibited complex patterns. Young adults, who most frequently presented with rhinitis alone (86.0%), were mainly sensitized to grass (29.5%), weed pollen (24.7%), and cat dander (13.0%); these rates were all significantly higher than those in middle-aged and elderly adults (p<0.01). Middle-aged and elderly adults, in contrast, showed significantly higher rates of mite sensitization than younger adults (up to 66.7%; p<.001 for both age groups). In these age groups, rhinitis was more frequently accompanied by asthma (10.3%) or urticaria (14.6%) (p<.01).

Conclusion: Allergen sensitization among adults with rhinitis demonstrates a dynamic, age-dependent pattern. Sensitization to pollen and pets predominates in younger adults, whereas sensitization to mites persists and intensifies with advancing age and comorbidities. These findings highlight age as a key determinant, whose effects are shaped by both immunologic and behavioral and environmental factors, underscoring the need for personalized, age-adapted approaches in allergy management.

Keywords: Allergic rhinitis, Allergen sensitization, Polysensitization, Asthma, Urticaria
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INTRODUCTION

Allergic rhinitis (AR) is one of the most prevalent chronic allergic disorders, affecting 10–40% of the adult population worldwide [1]. It is associated with significant impairment in quality of life, reduced work productivity, and frequent comorbidities [2]. Among these, asthma is a major comorbidity

and a significant risk factor among patients with rhinitis, reflecting their frequent coexistence and shared inflammatory mechanisms [3]. Urticaria, although not a classical comorbidity, may also coexist with rhinitis as an associated allergic condition. Prevalence studies indicate a significant overlap, which contributes further to disease burden [4].

Patterns of allergen sensitization exhibit substantial variability across environmental exposures, geographic regions, and age groups [5, 6]. While pediatric studies often report a predominance of pollen sensitization, adult studies sometimes emphasize sensitization to mites or molds. However, these patterns are not universal and may shift depending on geographic location or comorbidity status, such as asthma [6, 7]. Furthermore, data from large, longitudinal adult cohorts remain limited.

Another important clinical challenge is polysensitization, defined as sensitization to multiple, often unrelated, allergen groups [8]. Polysensitization and complex combinations, such as simultaneous pollen and indoor allergen reactivity, are frequently encountered in clinical practice and complicate therapeutic decisions, particularly in allergen immunotherapy (AIT) [9].

Despite the high prevalence and clinical impact of AR, there is a lack of large-scale studies systematically evaluating age-related differences in allergen sensitization among adults with rhinitis. Moreover, the interplay among rhinitis, asthma (its major comorbidity), and urticaria (an associated allergic condition) across different age groups has not been fully elucidated.

Therefore, this study aimed to analyze age-specific patterns of inhalant allergen sensitization in a large cohort of adult patients with clinically diagnosed rhinitis and to assess coexisting asthma and urticaria.

MATERIALS AND METHODS

Study design and population

This retrospective, single-center study was conducted at the Adult Allergy and Clinical Immunology outpatient clinic of Necmettin Erbakan University Faculty of Medicine, a tertiary referral hospital in Türkiye. Between 2022 and 2024, 7,000 adults underwent skin-prick testing (SPT) for suspected allergic diseases. Of these, 1,982 patients were diagnosed with rhinitis based on clinical history and physical examination and included in the analysis.

Study for ethical approval was obtained from the Clinical Research Ethics Committee of Necmettin Erbakan University (Approval No: 2025/5660). All procedures were carried out in accordance with the principles of the Declaration of Helsinki. Patient identities were anonymized, and data protection regulations were strictly observed.

Clinical assessment

The diagnosis of rhinitis was established based on clinical symptoms (nasal obstruction, rhinorrhea, sneezing, and/or itching) persisting for at least 12 months and supported by allergen sensitization results. Coexisting asthma and urticaria were identified based on medical history, physician diagnosis, and clinical documentation. Asthma was considered a major comorbidity of rhinitis, whereas urticaria was classified as an associated allergic condition.

Skin prick testing

SPT was performed using a standardized panel of inhalant allergens, from which the following were selected for evaluation: pollens (grass mix, tree mix, weed mix); mites (*Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*); mold (*Alternaria alternata*); cockroach (*Blattella germanica*); and pet dander (cat, dog). Histamine (10 mg/mL) and saline were used as positive and negative controls, respectively. A test was considered positive when the mean wheal diameter was at least 3 mm greater than that of the negative control after 15 minutes. All procedures were performed by trained allergy nurses under physician supervision.

Age grouping

Patients were categorized into three age groups: young adults (18–39 years), middle-aged adults (40–64 years), and older adults (≥65 years), consistent with commonly used epidemiologic classifications [10].

Definition of polysensitization and complex polysensitization

Polysensitization was defined as sensitization to two or more allergens on the skin-prick test panel. Complex polysensitization was defined as sensitization across different allergen groups, such as pollen, indoor arthropods (mites and cockroaches), mold, or pet dander.

Statistical analysis

Data were analyzed using IBM SPSS Statistics, version 22 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as frequencies and percentages. Group comparisons were performed using chi-square tests. A p-value < 0.05 was considered statistically significant. All p-values were adjusted for multiple comparisons using the Bonferroni correction and are reported as adjusted p-values.

RESULTS

Study population

Of the 7,000 adults screened, 1,982 patients were clinically diagnosed with rhinitis and included in the analysis. The median age was 32 years (IQR 24–43), with 62% classified as young adults (18–39 years), 32% as middle-aged adults (40–64 years), and 6% as elderly adults (≥65 years).

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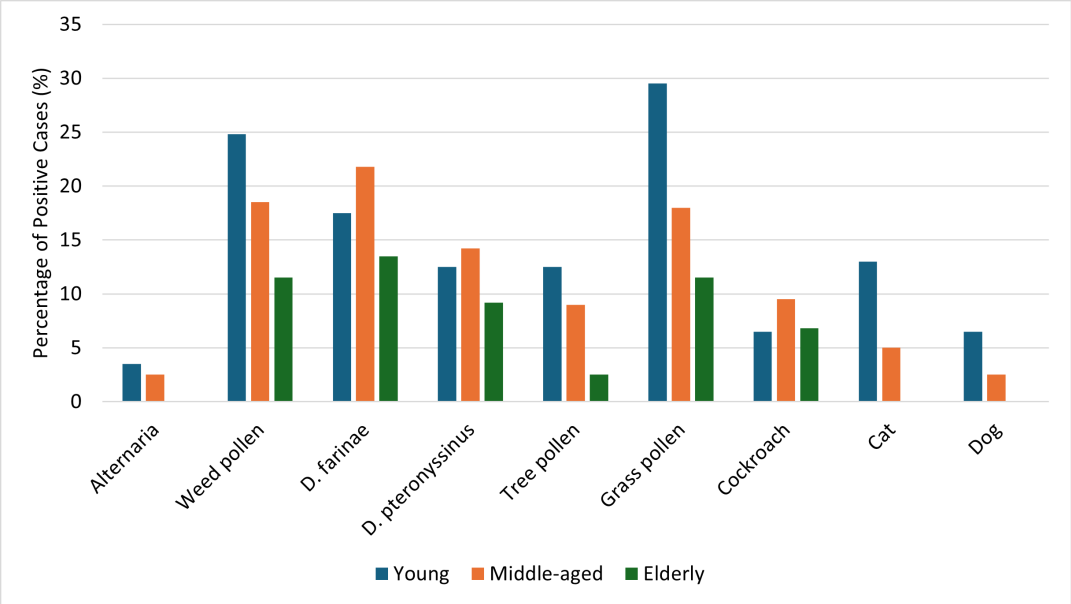

Figure 1. Age-related distribution of inhalant allergen sensitization in adults with rhinitis. Bars represent the percentage of positive cases for each allergen among young, middle-aged, and elderly adults. Red asterisks indicate statistically significant differences among age groups (Bonferroni-adjusted p<0.05).

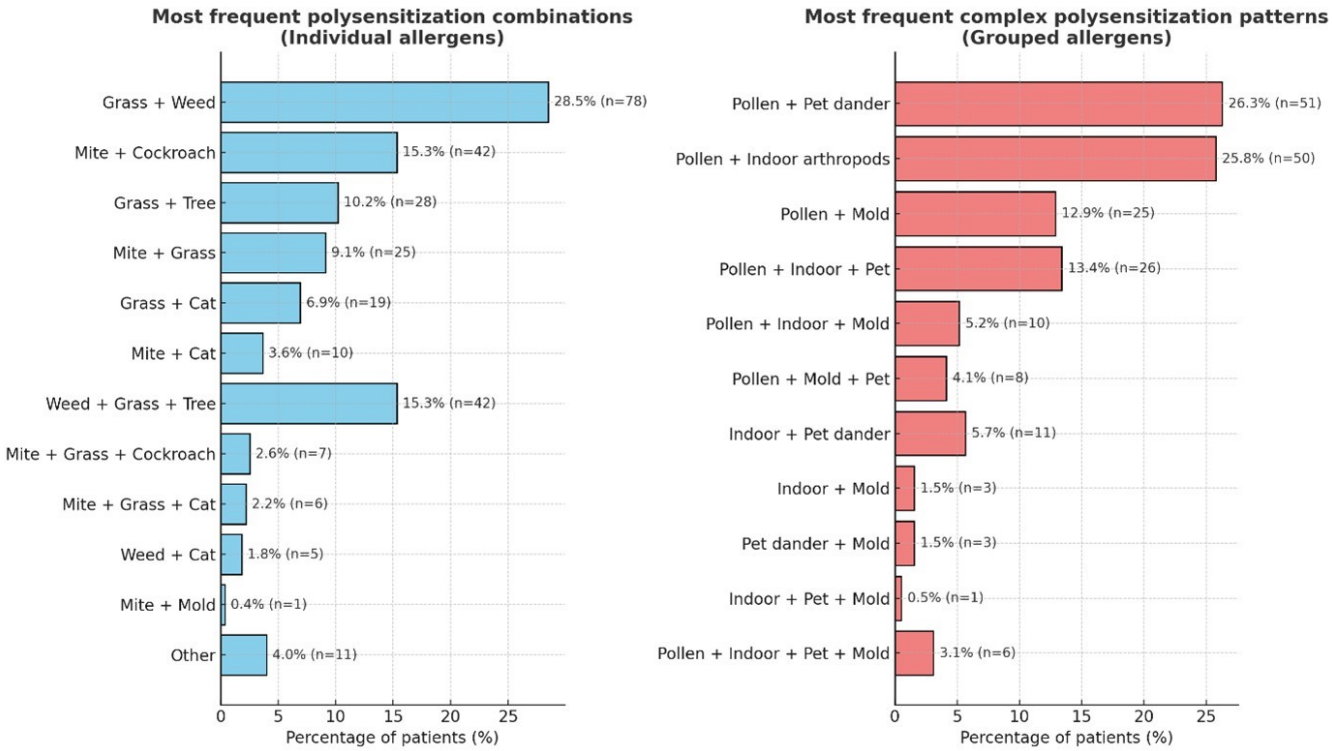

Figure 2. Distribution of allergen combinations among polysensitized patients based on individual allergens and grouped allergen categories. The left panel shows combinations based on individual allergens, and the right panel shows grouped combinations categorized as indoor arthropods (mites or cockroach), pollens (grass, tree, weed), pet dander (cat or dog), and molds (Alternaria). Bars indicate the percentage of patients, with the number of patients shown in parentheses.

Overall sensitization rates

Overall, 58.5% (n=1160) of patients demonstrated sensitization to at least one inhalant allergen. An age-related pattern emerged, with sensitization rates declining across age groups: 62.0% in young adults, 52.7% in middle-aged adults, and 29.5% in elderly adults (p<.001 for all pairwise comparisons). Among those sensitized, 620 individuals (53.4%) demonstrated monosensitization, indicating sensitivity to a single allergen. Polysensitization was present in 540 patients (46.6%). Of these, 342 (29.7% of all sensitized patients) demonstrated complex polysensitization, defined as sensitization across multiple distinct allergen groups. No significant

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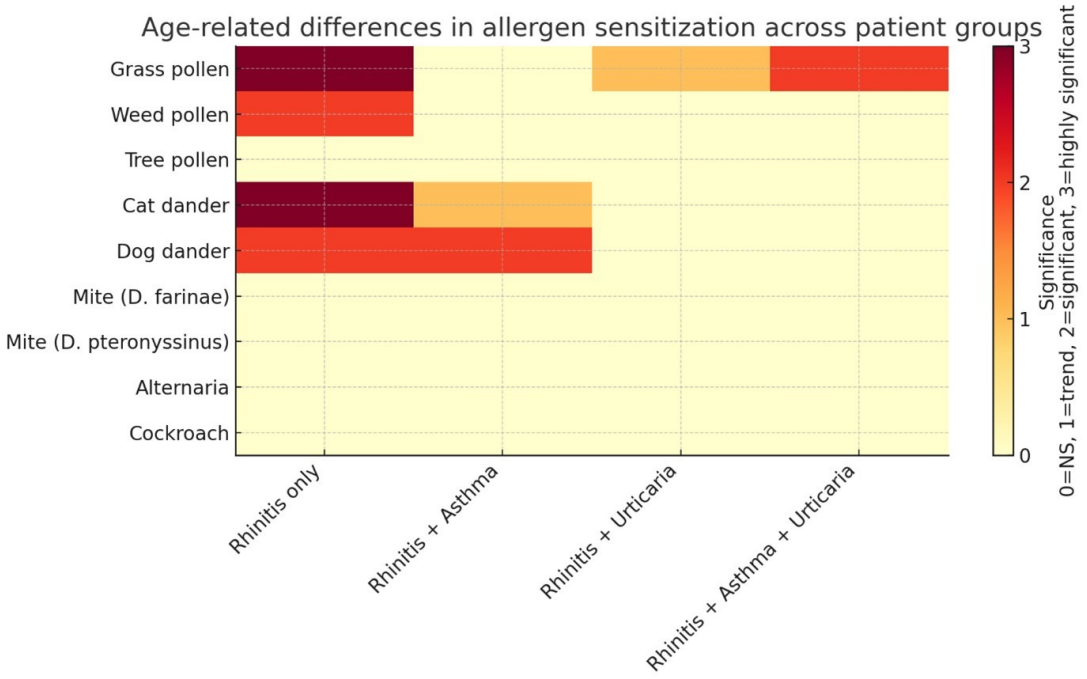

Figure 3. Age-related differences in allergen sensitization among patients with rhinitis, rhinitis with asthma, rhinitis with urticaria, and rhinitis with both asthma and urticaria. Heatmap colors indicate the level of statistical significance across age groups (0 = not significant, 1 = trend, 2 = significant, 3 = highly significant). Statistical significance indicated in the figure is based on Bonferroni-adjusted p values.

Table 1. Comparison of demographic and allergen sensitization characteristics across age groups.

Variable	Young adults (n=1352)	Middle-aged (n=586)	Elderly (n=44)	p-value	Age-related trend
Female	966 (71.4%)	385 (65.7%)	27 (61.4%)	.020	Young > Middle
Any sensitization	838 (62.0%)	309 (52.7%)	13 (29.5%)	<.001	Young > Others Middle > Elderly
Polysensitization	408 (48.2%)	129 (41.9%)	8 (61.5%)	0.13	NS
Complex polysensitization	262 (31.3%)	79 (25.6%)	6 (46.2%)	.09	NS

Values are presented as n (%). Adjusted post-hoc comparisons (Bonferroni correction) were applied. NS = not significant.

Table 2. Symptom distribution by age group.

Symptom Group	Young adults (n=1352)	Middle-aged (n=586)	Elderly (n=44)	p-value	Age-related trend (Bonferroni)
Rhinitis	1161 (86.0%)	426 (72.7%)	36 (81.8%)	<.001	Young > Middle
Rhinitis + Asthma	82 (6.1%)	60 (10.2%)	3 (6.8%)	.001	Middle > Young
Rhinitis + Urticaria	93 (6.9%)	85 (14.5%)	1 (2.3%)	<.001	Middle > Young
Rhinitis with both asthma and urticaria	14 (1.0%)	13 (2.2%)	4 (9.1%)	<.001	Elderly > Others
Unclassified phenotype	2 (0.1%)	2 (0.03%)	-	-	-

Values are presented as n (%). Bonferroni-adjusted post-hoc comparisons applied.

differences were observed across age groups (p=0.13 and 0.09, respectively). Baseline demographic and sensitization characteristics across age groups are summarized in Table 1.

Age-related allergen sensitization patterns

Age-specific analysis revealed distinct sensitization trends. Young adults exhibited significantly higher sensitization rates to grass pollen (29.5% vs. 18.8% vs. 13.6%, p< .001), weed pollen (24.7% vs. 18.6% vs. 11.4%, p= .001), cat (13.0% vs. 4.9% vs. 0%, p< .001), and dog (6.5% vs. 2.4% vs. 0%, p=.003) than those in the middle-aged and elderly groups. In contrast, sensitizations to house dust mites (*Dermatophagoides farinae* and *D. pteronyssinus*) and mold (*Alternaria*) did not differ significantly across age categories (p>0.05; Figure 1).

Age related mono- and polysensitization patterns

Among monosensitized patients (n=620), sensitization was most frequently directed against house dust mites (*Dermatophagoides pteronyssinus* and *D. farinae*; n = 260, 41.8%), followed by grass pollen (n=120, 19.3%) and cat dander (n=35, 5.6%). Other allergens, including tree pollen, cockroach allergens, mold, and dog dander, were observed in a small minority of patients. Sensitization to mites alone was significantly more frequent in middle-aged adults compared

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with young adults (36.3% vs. 24.5%, p=0.013), a difference primarily driven by *D. farinae* (p<0.001). Grass pollen was the second most common monosensitization pattern and significantly more frequent in young adults than in middle-aged adults (22.9% vs. 11.7%, p=0.007), while no significant differences were observed between the elderly and other age groups.

Among patients with polysensitization, the most frequent combinations of individual allergens were grass and weed pollens (28.5%), followed by mite and cockroach (15.3%) and weed, grass, and tree pollens (15.3%) (Figure 2, left). Age-stratified analysis showed that Pollen-based combinations predominated in young adults, whereas mite-plus-cockroach combinations were more common in middle-aged adults. Although the overall Chi-square test indicated a significant difference across age groups (p=0.045), the results should be interpreted with caution because of small cell counts.

When allergens were analyzed in grouped categories, the most common complex patterns were pollen with pet dander (26.3%) and pollen with indoor arthropods (25.8%), followed by pollen with mold (12.9%) and pollen with indoor arthropods plus pet dander (13.4%) (Figure 2, right). No significant differences were observed in the distribution of complex polysensitization patterns across age groups (p>.05).

Age-related distribution of clinical phenotypes and allergen sensitization patterns

When participants were stratified by clinical phenotype, distinct age-specific allergen sensitization profiles were observed, with significant differences across age groups highlighted in the heat map (Table 2, Figure 3).

Rhinitis alone

Rhinitis without comorbidities was more common in young adults than in middle-aged adults (86.0% vs. 72.9%, P_adj < .001). In this group, sensitizations predominantly involved grass (28.9% vs 17.1% vs 11.1%, $P_a$dj <.001), weed (25.1% vs 17.9% vs 5.6%, $P_a$dj =.001), and tree pollens (12.5% vs 9.0% vs 2.3%, $P_a$dj =.037), as well as cat (12.3% vs 4.2% vs 0%, $P_a$dj <.001) and dog dander (6.6% vs 2.6% vs 0%, $P_a$dj=.003), all of which were significantly more frequent in young adults. Among middle-aged adults with rhinitis alone, weed (17.9%) and grass (17.1%) represented the leading sensitizations, whereas in elderly adults *D. farinae* (13.9%) and grass pollen (11.1%) were most frequent (Table 2, Figure 3).

Rhinitis with asthma

The coexistence of rhinitis and asthma was more frequent in middle-aged adults than in young adults (10.3% vs. 6.1%; p=.001). In young adults with this phenotype, sensitizations to cat dander (12.7% vs 5.0%, p = .01) and dog dander (7.8% vs 2.3%, p=.005) were significantly more common. By contrast, in middle-aged adults, the most common sensitizations were to house dust mites (19.7% for *D. farinae*; 18.9% for *D. pteronyssinus*), followed by grass pollen (15.4%). Among elderly adults, sensitizations were again largely confined to house dust mites, with *D. farinae* (66.7%) and *D. pteronyssinus* (33.3%) constituting the only positive allergens identified (Figure 3).

Rhinitis with urticaria

The co-occurrence of rhinitis and urticaria was more common in middle-aged adults than in young adults (14.6% versus 6.9%; p<0.001). In this group, sensitizations were mainly directed against house dust mites (*D. farinae*, 50.6%; *D. pteronyssinus*, 31.8%) and grass pollen (27.1%), whereas cat (19.4% vs. 9.4%) and dog dander (7.5% vs. 1.2%) sensitizations were more common in young adults (p=.002 and p=.007, respectively). In older adults with rhinitis and urticaria, sensitizations were again confined to house dust mites (100% for both *D. farinae* and *D. pteronyssinus*; Figure 3).

Rhinitis with both asthma and urticaria

This phenotype was rare overall, but was more prevalent among elderly adults than in other age groups (9.1%, 2.2%, and 1.0%; p<0.001). In this group, sensitizations were largely limited to house dust mites (*D. farinae*, 22.7%; *D. pteronyssinus*, 20.5%), whereas sensitizations to pollen and animal dander were negligible (Figure 3). In contrast, cases of rhinitis with both asthma and urticaria were rare among young and middle-aged adults, and no consistent sensitization pattern was observed.

DISCUSSION

This large-scale study of approximately 2,000 adults with clinically diagnosed rhinitis characterizes age-related patterns of allergen sensitization and associated clinical phenotypes.

Our findings address this gap by demonstrating that allergen sensitization and disease expression in adults are not static but rather evolve with age, reflecting both environmental exposures and immunologic changes. Younger adults were more frequently sensitized to pollen and pet dander, typically presenting with isolated rhinitis, whereas middle-aged adults more often exhibited rhinitis accompanied by asthma or urticaria, with sensitization shifting toward house dust mites. Among elderly adults, sensitization patterns were almost exclusively limited to mites, while comorbid conditions frequently persisted. Across all age groups, polysensitization was common, and nearly one-third of sensitized patients demonstrated complex polysensitization involving multiple allergen groups, further highlighting the heterogeneity and evolving complexity of allergic disease in adulthood. Collectively, these results emphasize that age influences not only the prevalence but also the pattern and clinical complexity of allergic disease, underscoring the dynamic and multifactorial nature of allergen sensitization throughout adulthood.

Our findings showed that, with advancing age, comorbidities such as asthma and urticaria became more frequent, suggesting that chronic inflammation and long-term allergen ex-

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posure may sustain disease activity despite a general decline in sensitization diversity. Consistent with this, house dust mite sensitization remained stable and even became relatively more prominent in later decades, whereas sensitization to pollens and animal dander declined. These age-related shifts likely reflect the combined effects of immunosenescence, epithelial remodeling, and behavioral factors and are consistent with previous reports indicating persistence of sensitization to perennial allergens but waning of sensitization to seasonal allergens in older adults [11,12]. While this pattern may partly reflect immunologic mechanisms such as immunosenescence and reduced generation of new sensitizations, it may also be influenced by behavioral and environmental factors. Age-related remodeling of immune regulation—including reduced Th2 polarization, impaired dendritic cell function, and alterations in IgE memory responses—may weaken sensitization to newly encountered aeroallergens while maintaining reactivity to persistent indoor antigens such as mites [13,14]. In addition, lifestyle and environmental factors may reinforce these patterns, as younger adults are more likely to own pets and spend time outdoors, increasing exposure to pollen and animal dander, whereas middle-aged and elderly adults tend to remain indoors and have greater contact with dust mites. This concept is further supported by observations during the COVID-19 pandemic, when prolonged indoor confinement was associated with increased sensitization to indoor allergens such as mites and molds]15,16].

In younger adults, where pollens and animal dander are the predominant allergens, early recognition and timely initiation of immunotherapy may prevent disease progression and improve long-term outcomes. In clinical practice, as demonstrated in our study, dual positivity for grass pollen and cat dander is frequently observed in young adults with rhinitis. This pattern is generally interpreted as true co-sensitization rather than cross-reactivity, particularly when clinical manifestations are consistent with both exposures—such as worsening of symptoms during grass pollen seasons and persistence of symptoms indoors in households with a cat. Although cat removal is theoretically recommended to reduce allergen exposure, adherence to this measure remains low, with studies reporting implementation rates ranging from approximately 4% to 35% [17,18]. In these patients, conventional intranasal or systemic antiallergic therapy often provides suboptimal symptom control, underscoring the need for allergen-specific interventions. In co-sensitized adults, allergen immunotherapy remains effective when the clinically dominant allergen is targeted. However, robust evidence specifically addressing the outcomes of pollen immunotherapy in patients with a household cat and a concurrent clinically relevant cat allergy is scarce. Moreover, this coexistence may contribute to additive epithelial stress and

Inflammation occurs because both pollen and cat dander are known to induce innate oxidative and inflammatory responses in the airway epithelium [19]. The optimal management strategy for this frequently encountered co-sensitization pattern remains an open and largely unexplored area of research.

In middle-aged adults, asthma was more commonly associated with rhinitis, and mite sensitization was dominant, underscoring the central role of indoor allergen exposure in sustaining allergic airway disease. This pattern may reflect cumulative allergen exposure over time, as well as structural and immunologic remodeling of the airway epithelium, which could favor persistent sensitization to perennial allergens such as mites [20]. Similarly, in elderly adults, sensitization was largely confined to mites, while comorbid conditions such as asthma and urticaria frequently persisted in association with rhinitis [21,22]. Taken together, these findings suggest that early identification and mite-targeted management in middle-aged adults may not only improve symptom control at that life stage but may also help prevent the persistence or progression of comorbid allergic conditions in later decades. Furthermore, the present finding that mites were the most frequent allergens among monosensitized patients particularly when comorbid conditions are present—suggests that mite sensitization may represent a consistent and effective target for allergen immunotherapy across all age groups.

In our study, Polysensitization was observed in nearly half of the sensitized adults, with one-third of these individuals exhibiting complex patterns across multiple allergen groups. Comparable findings have been reported in a Korean adult cohort (prevalence of polysensitization, 41.3%), in a Finnish cohort (sensitization to more than three allergens observed in up to 56% of participants), and in a German cohort (polysensitization rates as high as 81%) [23-25]. The clinical importance of such broad sensitization profiles is further supported by multicenter data showing that increasing disease severity is linked to higher polysensitization rates, contributing to the heterogeneity of allergic rhinitis [26]. At the diagnostic level, discrepancies between skin prick testing and component-resolved diagnostics have been demonstrated, highlighting the need for molecular characterization in polysensitized patients [27]. Collectively, these findings indicate that polysensitization is both common and clinically relevant, and that precise molecular identification of the dominant allergen may be essential for optimizing diagnosis and therapy.

In Turkiye, studies of aeroallergen sensitization in adults have primarily reported the frequencies of common allergens, with pollens and house dust mites variably identified as the most prevalent sensitizing agents, even within studies conducted within the same geographic regions [28-30]. However, such frequency-based reporting alone provides limited insight into allergen–disease relationships. In a cohort from Şanlıurfa, Erbay demonstrated that while pollen sensitization was common among patients with allergic rhinitis, house dust mite sensitization was significantly more frequent in patients with isolated asthma [31]. Similarly, in the South Marmara region, Ediger et al. reported that pollen sensitization predominated

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in patients with rhinitis alone, whereas house dust mites were more frequent among those with concomitant rhinitis and asthma [29]. Our study expands this limited national literature by not only confirming phenotype-dependent sensitization patterns observed in previous studies, such as the predominance of house dust mite sensitization in patients with asthma, but also integrating age-stratified allergen sensitization, polysensitization profiles, and associated clinical phenotypes in a single, large adult cohort.

This approach allows for a dynamic and clinically relevant understanding of allergic disease that goes beyond simple prevalence reporting.

Limitations

Limitations of our study include its retrospective design, single-center setting, and reliance on skin prick testing without complementary molecular diagnostics such as CRD. The relatively small number of elderly patients also limits the generalizability of findings in this subgroup. Nevertheless, the large overall sample size, systematic age-stratified evaluation, and incorporation of comorbid allergic symptom profiles represent key strengths of this study.

CONCLUSION

This study demonstrates that allergen sensitization patterns and clinical phenotypes in adults are dynamic and age-dependent. Isolated rhinitis in young adults is primarily driven by pollen and animal dander, whereas mite sensitization predominates in middle-aged and older adults, and is often accompanied by asthma and urticaria. In this context, the high burden of polysensitization underscores the need for advanced diagnostic approaches and supports a more personalized, age-tailored strategy in allergy practice, integrating phenotypes and sensitization patterns to guide diagnostic, preventive, and therapeutic decisions.

Ethics Committee Approval: This study approval was obtained from the Necmettin Erbakan University Non-Interventional Research Ethics Committee (Approval No: 2025/5660).

Informed Consent: It was not deemed necessary due to the retrospective nature of the study.

Peer-review: Externally peer-reviewed.

Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions: Conceptualization: TO, FÇ, ŞA. Methodology: TO, FÇ, MEG. Formal analysis: TO, MEG, MK. Data curation: FAA, MK, FSA. Investigation: TO, FAA, MK, FSA. Visualization: TO, MEG. Writing – original draft: TO. Writing – review & editing: TO, FÇ, ŞA. Supervision: FÇ, ŞA. Project administration: TO, FÇ. Resources: ŞA.

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