Association between allergic rhinitis and attention deficit hyperactivity disorder symptoms in pediatric patients: the impact of seasonal variability

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Rhinology 64: 2, 0 - 0, 2026
https://doi.org/10.4193/Rhin25.185

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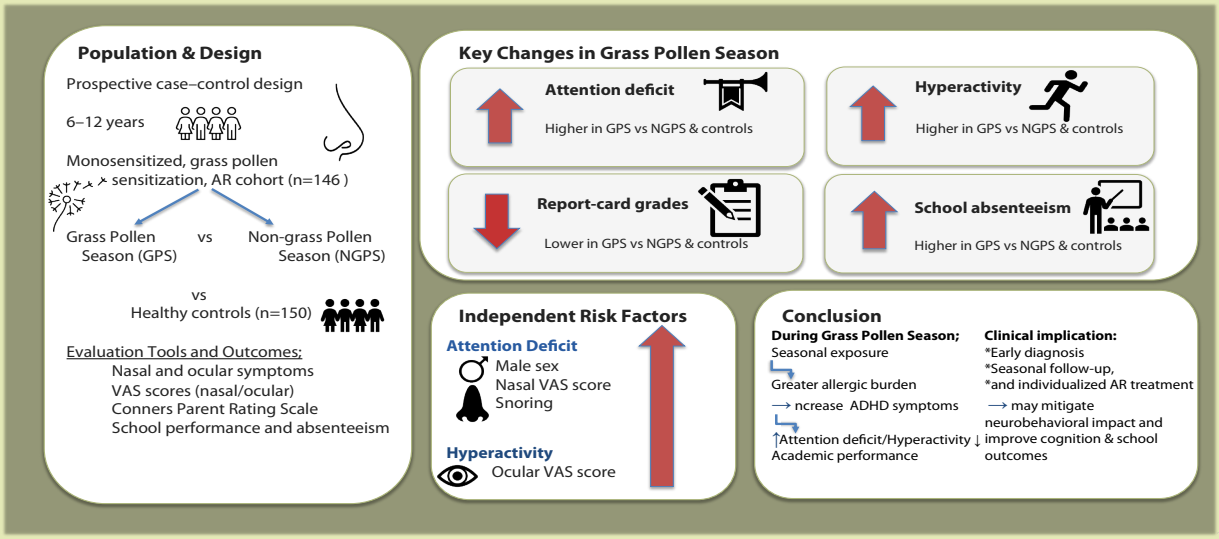

Sogut A, Selmanoglu A, Genis C, et al. Rhinology 2026. https://doi.org/10.4193/Rhin25.185

Abstract

Background: Allergic rhinitis (AR) patients may experience attention deficits (AD), concentration impairment, and learning difficulties. This study aimed to compare AD hyperactivity disorder (ADHD) symptoms in grass pollen–allergic AR patients and controls and to assess their seasonal variation.

Methodology: The study included children aged 6–12 with AR who presented to Ankara Bilkent City Hospital between April 15 and June 15 in 2022 and 2023. The Visual Analog Scale (VAS) was used to assess disease severity, and the Conners Parent Rating Scale (CPRS) was employed to evaluate ADHD symptoms. For comparison, the CPRS was also administered to an age-matched control group consisting of children without known allergies or chronic diseases.

Results: The study included 146 AR patients (8.9±1.7 years) and 150 controls (9.0±1.8 years). During the grass pollen season, AR patients showed increased rates of AD, hyperactivity, and school absenteeism, along with a decline in academic performance. Compared to the control group, AR patients exhibited significantly higher AD, hyperactivity, and total CPRS scores. Logistic regression analysis identified male sex, high nasal VAS score, and snoring as independent risk factors for AD, while a high ocular VAS score was an independent risk factor for hyperactivity.

Conclusions: Exacerbation of AR symptoms during the grass pollen season leads to a significant increase in ADHD symptoms and a decline in academic performance. Regular monitoring and symptom control in AR patients are crucial for maintaining academic and social success.

Key words: allergic rhinitis, attention deficit hyperactivity disorder, seasonal variability, pediatric allergy, cognitive impairment

Introduction

Rhinitis is an inflammation of the nasal mucosa presenting with sneezing, rhinorrhea, congestion, and itching. Allergic rhinitis (AR) is a subtype of rhinitis, mediated by IgE, with the diagnosis established clinically and confirmed by skin prick testing (SPT) and/or serum-specific immunoglobulin E (sIgE) measurement [1].

Attention deficit hyperactivity disorder (ADHD) is a common neurodevelopmental disorder marked by inattention, hyperactivity, and impulsivity. DSM-5 recognizes three subtypes: inattentive, hyperactive-impulsive, and combined. Diagnosis relies on DSM-5 criteria, requiring symptoms for ≥6 months, onset before age 12, presence in multiple settings, and functional impairment. In pediatric research, validated tools such as the Conners Parent Rating Scale (CPRS) are widely used to assess ADHD domains [2,3].

Patients with AR experience not only the discomfort caused directly by their symptoms but also neurocognitive issues such as attention deficits (AD), concentration difficulties, and learning impairments due to associated comorbidities [4]. ADHD has been reported at a higher prevalence in individuals with AR [5,6].

AR and ADHD frequently occur in overlapping age groups, and the presence of ADHD-related symptoms such as AD, irritability, and hyperactivity in AR patients suggests a potential link between these two conditions [7]. However, the exact mechanism underlying the relationship between AR and ADHD, as well as the impact of seasonal allergen exposure on this association, remains unclear. Although recent evidence syntheses have confirmed a bidirectional association between AR and ADHD, the majority of included studies were diagnosis-based, with only limited reliance on symptom scales, and none assessed seasonal or repeated symptom-scale variations in relation to ADHD manifestations [8,9]. Therefore, there is a need for prospective studies focusing on seasonal variation and its functional consequences.

This study aimed to examine the seasonal variation of AR symptoms and ADHD manifestations in children with AR and to evaluate their impact on academic performance and school absenteeism, thereby addressing gaps in the literature. We hypothesized that ADHD symptoms in AR patients with grass pollen allergy (GPA) would show seasonal variation, with a significant increase during the grass pollen season (GPS).

Materials and methods

Study design and participants

This prospective case–control study included children aged 6–12 years who were diagnosed with AR due to GPA and presented to the Pediatric Allergy Clinic of Ankara Bilkent City Hospital between April 15 and June 15 in 2022 and 2023. The study was approved by the institutional ethics committee (Decision No: E2-22-1625), and written informed consent was obtained from all parents and children after full disclosure.

To minimize confounding and ensure a homogeneous study population, only children monosensitized to grass pollen were included, as grass pollen is a major seasonal allergen in Ankara, while patients with polysensitization to other seasonal or perennial aeroallergens were excluded.

None of the AR patients had chronic systemic diseases other than allergic conditions. Children with well-controlled asthma, defined according to the Global Initiative for Asthma (GINA) criteria, and mild atopic dermatitis, defined by the Scoring Atopic Dermatitis (SCORAD) index <25, were included; those not meeting these criteria were excluded [10,11].

The control group comprised age-matched children who attended the general pediatrics outpatient clinic during the same period and had no history of allergic or other chronic systemic diseases.

To minimize potential confounding, children who were receiving maintenance pharmacotherapy for ADHD or regular treatment for AR with oral or intranasal antihistamines, intranasal corticosteroids, or intranasal antihistamines were excluded from the study. Accordingly, none of the enrolled participants were on maintenance pharmacotherapy during the study period.

Clinical assessments and data collection

Data included socio-demographic characteristics, allergic symptoms, AR symptom onset and diagnosis age, nasal and ocular VAS scores, school absenteeism, and report card grades for fourth- and fifth-graders. Because grades were unavailable for first- to third-graders, they were excluded from academic performance analysis.

The GPS was defined as April 15–June 15, based on long-term aeropalynological surveys in Ankara, which also identified *Lolium perenne*, *Dactylis glomerata*, *Phleum pratense*, and *Poa pratensis* as the predominant grass pollens [12]; the remainder of the year was considered the non-grass pollen season (NGPS). In Türkiye, the first semester runs from September to January, and the second from February to June; thus, the NGPS corresponds to the first semester, while the GPS coincides with the second semester.

Classification of allergic rhinitis

The classification of AR was based on the Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines. The frequency of symptoms was classified as intermittent or persistent. The severity of AR was classified as mild or moderate/severe [13].

Allergen sensitization assessment

All patients were diagnosed with GPA based on SPT and/or sIgE testing, with no additional sensitivities detected. A comprehensive aeroallergen panel (Lofarma®, Milan) was used for SPT on the volar forearm, with histamine and saline as positive and negative controls. A wheal ≥3 mm was considered positive [14].

Table 1. Baseline demographic and clinical characteristics of the study population.

Characteristics	Total (n=296)	AR group (n=146)	Control (n=150)	p-value
Child age, years (mean ± SD)	9.0 ± 1.7	8.9 ± 1.7	9.0 ± 1.8	0.621
Sex, n (%)	Female: 125 (42.2%) Male: 171 (57.8%)	Female: 48 (32.9%) Male: 98 (67.1%)	Female: 77 (51.3%) Male: 73 (48.7%)	**<0.001**
Concomitant allergic diseases	—	Atopic dermatitis 12 (8.2%) Asthma 15 (10.2%)	—	—
AR severity	—	Mild: 76 (52.1%) Moderate/severe: 70 (47.9%)	—	—
AR pattern	—	Intermittent: 84 (57.5%) Persistent: 62 (42.5%)	—	—

AR: Allergic rhinitis; VAS: Visual Analog Scale; SD: Standard deviation; IQR: Interquartile range.

sIgE was measured using the Immulite 2000 system (Siemens®, NY), with ≥0.35 U/mL defining positivity [15].

ADHD symptom assessment

ADHD symptoms were assessed during GPS and NGPS using the Conners Parent Rating Scale (CPRS), completed by parents. This 48-item tool evaluates AD, hyperactivity, oppositional defiant behavior (ODB), and conduct disorder (CD), with higher scores indicating greater severity. Pathological cases were defined as values >2 SD above the mean [16]. In Turkish children, validated cutoffs were AD ≥5, hyperactivity ≥6, ODB ≥6, and CD ≥18 [17]. Patients exceeding these cutoffs were referred to Child Psychiatry for further evaluation.

Follow-up procedures

During follow-up examinations after GPS, the symptoms, VAS scores, medication use, absenteeism, and report card grades of AR patients during NGPS were reassessed. To determine changes in ADHD symptoms, the CPRS was re-administered in the AR group during both the GPS and the NGPS, whereas in the control group, it was administered only once. This single assessment in the control group was not classified by season (i.e., not assigned to GPS or NGPS)

Outcomes and covariates

The pre-specified primary outcomes were the CPRS subscales of AD and hyperactivity assessed during the GPS. The main exposures for comparative analyses were season (GPS vs. NGPS) and group (AR vs. controls). Within the AR cohort during GPS, risk-factor analyses were conducted only for these primary outcomes (see Statistical Analysis for details). Candidate covariates included age, sex, nasal VAS, ocular VAS, snoring, and AR severity. The ODB and CD subscales were summarized descriptively and compared between groups; however, they were not modeled as dependent outcomes because they were not pre-specified primary endpoints. School absenteeism and report-card grades were examined as secondary outcomes.

Statistical analysis

Statistical analyses were conducted with SPSS v26.0. Normality was assessed using the Shapiro–Wilk test. Descriptive data were presented as mean ± standard deviation (SD) for normally distributed and as median with interquartile range (IQR, 25th–75th percentile) for non-normally distributed variables. For continuous variables, Student's t-test was applied to normally distributed and Mann–Whitney U test to non-normally distributed data, while categorical variables were compared using the chi-square test. For paired analyses, the Wilcoxon test was applied to non-normally distributed continuous data and the McNemar test to categorical data.

To identify risk factors for ADHD symptoms, univariate analyses were initially performed, and variables with a p-value<0.25 were subsequently considered for multivariable modeling. For these analyses, we constructed two logistic regression models restricted to the AR cohort during the GPS, with AD and hyperactivity as the dependent variables. Candidate predictors included age, sex, nasal and ocular VAS scores, snoring status, and AR severity. Results are presented as adjusted odds ratios (OR) with 95% confidence intervals (CI). Continuous predictors such as age, nasal and ocular VAS scores were entered into the logistic regression model as continuous variables without dichotomization. Thus, the reported OR reflects the change in odds per one-point increase in the VAS score. A significance level of $p<0.05$ was considered statistically significant for all analyses. Given the hypothesis-generating exploratory design and interrelated outcomes, no additional multiple-testing correction was applied. Exact p-values, together with effect sizes and 95% CI, were reported and interpreted with caution to ensure transparency.

An a priori power analysis (Cohen's d=0.5, α=0.05, power=0.95) showed that at least 105 participants per group were required. Taking possible dropouts into account, 150 were recruited per group. With the final sample (n_1=146, n_2=150), a post hoc analysis confirmed adequate power, achieving a statistical power of 0.99.

Table 2. Comparison of patients' grass pollen season and non-grass pollen season symptoms and visual analog scale scores.

Parameters	Grass pollen season (n=146)	Non-grass pollen season (n=146)	p-value
Nasal symptoms (n, %)	146 (100)	56 (38.6)	**<0.001**
Sneezing	131 (89.7)	38 (26)	**<0.001**
Nasal congestion	113 (77.4)	32 (21.9)	**<0.001**
Rhinorrhea	109 (74.7)	30 (20.5)	**<0.001**
Nasal itching	95 (65.1)	28 (19.1)	**<0.001**
Ocular symptoms (n, %)	102 (69.9)	19 (13.0)	**<0.001**
Ocular itching	94 (64.4)	14 (9.5)	**<0.001**
Ocular redness	81 (55.5)	9 (6.1)	**<0.001**
Tearing	79 (54.1)	8 (5.4)	**<0.001**
Snoring (n, %)	64 (43.8)	36 (24.7)	**<0.001**
Nasal symptoms VAS (Median, IQR)	6 (5-8)	0 (0-2)	**<0.001**
Ocular symptoms VAS (Median, IQR)	4 (0-7)	0 (0-0)	**<0.001**
Nasal and ocular symptoms VAS (Median, IQR)	6 (5-7)	0 (0-2)	**<0.001**

IQR: Interquartile Range.

Table 3. Comparison of school performance, absenteeism, and grass pollen season and non-grass pollen season conners parent rating scale scores between patient and control groups.

Parameters	Grass pollen season (n=146)	Non-grass pollen season (n=146)	Control (n=150)	p1	p2	p3
4-5th Grade GPA (Mean±SD)	83.5±9.6	85.0±9.6	84.2±8.8	**0.001**	0.807	0.162
Absenteeism (%)	80 (54.8)	50 (34.2)	57 (38)	**0.001**	**0.001**	0.435
Absenteeism Days (Median, IQR)	4 (2-5)	2 (1-3)	2 (2-3)	**<0.001**	**<0.001**	**0.004**
Attention Deficit (Median, IQR)	3 (1-5)	2 (1-3)	2 (0-3)	**<0.001**	**<0.001**	0.290
Hyperactivity (Median, IQR)	4 (1-6)	3 (1-5)	2 (0-4)	**<0.001**	**<0.001**	**0.025**
Oppositional Defiance (Median, IQR)	2 (0-4)	3 (0-3)	1.5 (0-4)	**0.006**	0.606	0.710
Conduct Disorder (Median, IQR)	2 (1-4)	2 (1-3)	2 (0-5)	**0.005**	0.991	0.469
Total CPRS Score (Median, IQR)	11 (5-17)	8.5 (4-13)	8 (3-13)	**<0.001**	**0.006**	0.643

p1: Comparison between patients during the grass pollen season and patients during the non-grass pollen season; p2: Comparison between patients during the grass pollen season and the control group; p3: Comparison between patients during the non-grass pollen season and the control group; CPRS: Conners Parent Rating Scale , IQR: Interquartile Range, SD: Standard Deviation.

Results

Baseline characteristics

This study included 146 children with AR and 150 controls. The mean age was similar between groups (8.9±1.7 vs. 9.0±1.8 years, p=0.621). Males were more prevalent in the AR group (67.1% vs. 48.7%, p=0.001). In the AR group, atopic dermatitis occurred in 12 patients (8.2%) and asthma in 15 (10.2%). 52.1% of patients were classified as mild and 47.9% as moderate-to-severe, while 57.5% had intermittent and 42.5% had persistent symptoms (Table 1).

Within-AR group comparisons (GPS vs. NGPS)

During GPS, nasal and ocular symptoms were highly prevalent, with a marked decline observed in NGPS; snoring also occurred more frequently in GPS. All differences were statistically significant (p<0.001).

VAS score analysis showed that the median (IQR) nasal symptom score was 6 (5–8) in GPS and 0 (0–2) in NGPS. Similarly, the median ocular symptom VAS score decreased from 4 (0–7) in GPS to 0 (0–0) in NGPS (p<0.001). Furthermore, the combined nasal and ocular symptom VAS score was significantly lower in NGPS (p<0.001) (Table 2).

School absenteeism rates and the number of absenteeism days were significantly higher in GPS compared to NGPS (p=0.001; p<0.001, respectively). Similarly, the mean report card grades of fourth- and fifth-grade students were significantly lower in GPS than in NGPS (p=0.001). Concordantly, CPRS scores for AD, hyperactivity, ODB, CD, and the total score were significantly

Table 4. Investigation of risk factors for attention deficit during the grass pollen season.

	UNIVARIATE			MULTIVARIATE		
	OR	CI	p	OR	CI	p
Age	1.101	0.929-1.306	0.266			
Male Sex	**3.163**	**1.671-5.988**	**<0.001**	**3.233**	**1.479-7.070**	**0.003**
VAS Nasal Symptoms	**1.200**	**1.088-1.325**	**<0.001**	**1.185**	**1.070-1.313**	**0.001**
VAS Ocular Symptoms	**1.168**	**1.067-1.278**	**0.001**			
Snoring	**2.079**	**1.150-3.759**	**0.015**	**1.950**	**1.046-3.637**	**0.036**
AR Severity	1.012	0.407-2.514	0.980			

AR: Allergic rhinitis, VAS: Visual Analog Scale.

Table 5. Investigation of risk factors for hyperactivity during the grass pollen season.

	UNIVARIATE			MULTIVARIATE		
	OR	CI	p	OR	CI	p
Age	1.098	0.912-1.322	0.322			
Male Sex	**2.060**	**1.108-3.830**	**0.022**			
VAS Nasal Symptoms	**1.113**	**1.008-1.230**	**0.035**			
VAS Ocular Symptoms	**1.174**	**1.069-1.288**	**0.001**	**1.157**	**1.020-1.312**	**0.024**
Snoring	1.350	0.722-2.525	0.347			
AR Severity	1.114	0.428-2.896	0.825			

AR: Allergic rhinitis, VAS: Visual Analog Scale.

higher in GPS compared to NGPS (p<0.001; p<0.001; p=0.006; p=0.005; p<0.001, respectively) (Table 3).

Comparison of CPRS scores between male and female AR patients showed significantly higher AD, hyperactivity, ODB, and total scores during GPS (males: p<0.001; p<0.001; p=0.046; p=0.030; p<0.001, females: p=0.002; p<0.001; p=0.043; p<0.001, respectively (Table S1).

Patients with at least one CPRS subscale above the validated cutoff were referred to Child Psychiatry. Referral occurred in 26.7% (39/146) of AR patients during GPS, 15.8% (23/146) in NGPS, and 16.0% (24/150) of controls. Rates were significantly higher in GPS than in NGPS (p=0.031) and controls (p=0.033), with no difference between NGPS and controls.

AR group (GPS and NGPS) vs. control group comparisons

When the characteristics of the AR group during GPS and NGPS were compared with those of the control group, AD, hyperactivity, and total CPRS scores were significantly higher in GPS (p<0.001; p<0.001; p=0.006, respectively). During NGPS, only the hyperactivity score remained significantly higher in the AR group (p=0.025), while no differences were observed for the other subscales. Absenteeism rates were also significantly increased in GPS compared to both NGPS (p=0.001) and the control group (p=0.001); however, no significant difference was observed between the AR and control groups during NGPS (Table 3).

Compared to the control group, male AR patients had significantly higher AD (p<0.001) and hyperactivity (p=0.002) scores in GPS. However, no statistically significant differences in CPRS scores were found between AR patients and the control group during NGPS (Table S1).

Additional subgroup analyses within the AR group

Children with moderate-to-severe AR had significantly higher AD (p=0.001), hyperactivity (p=0.010), and total CPRS scores (p=0.006) compared with those with mild disease. Similarly, ocular symptoms were also associated with higher AD (p=0.004) and total scores (p=0.021). In contrast, ODB and CD scores showed no significant differences by disease severity or ocular symptoms, and hyperactivity did not differ significantly with ocular symptoms.

Risk-factor analyses

Risk factors for AD and hyperactivity during GPS were assessed using univariate and multivariate logistic regression analyses. For AD, variables significant in the univariate analysis (male sex, nasal and ocular symptom VAS scores, and snoring) were entered into the multivariate model. The analysis identified male sex

(OR=3.233, 95% CI: 1.479–7.070, p=0.003), nasal symptom VAS score (OR=1.185, 95% CI: 1.070–1.313, p=0.001), and snoring (OR=1.950, 95% CI: 1.046–3.637, p=0.036) as independent risk factors (Table 4).

For hyperactivity, variables significant in the univariate analysis (male sex, nasal and ocular symptom VAS scores) were included in the multivariate model. The analysis demonstrated that only the ocular symptom VAS score remained an independent risk factor (OR=1.157, 95% CI: 1.020–1.312, p=0.024) (Table 5).

Discussion

This study aimed to investigate the variations in symptoms and neurobehavioral manifestations in children diagnosed with AR between GPS and NGPS and to assess their impact on academic performance and school absenteeism. The findings indicate a significant increase in AR symptoms during GPS, which not only affected nasal and ocular symptoms but also had a broader impact on cognitive and behavioral functions. This exacerbation contributed to a decline in academic performance and an increase in school absenteeism.

Tong et al. reported a mean age of 8.7 years and a higher prevalence in males (60.5%) among children with AR [18]. Consistently, our cohort had a mean age of 8.9 years, with 67.1% male, aligning with previous findings.

In our study, ocular and nasal VAS scores were significantly higher during GPS than NGPS, indicating that seasonal allergen exposure exacerbates AR symptoms. These results underscore the importance of early diagnosis, regular follow-up, and appropriate treatment for effective symptom control.

Academic success influences students' social relationships, future socioeconomic status, and lifestyle. Neuropsychiatric conditions accompanying AR—such as behavioral problems, inattention, hyperactivity, impulsivity, and anxiety—may adversely affect school performance [19]. Previous studies have demonstrated that academic outcomes improve during asymptomatic phases and with treatment adherence, but decline during symptomatic periods [20,21]. Consistently, our study demonstrated that report card grades of fourth- and fifth-grade AR patients were significantly higher in NGPS than in GPS, with no differences compared to controls. This suggests that improved performance may result from reduced pollen exposure and effective treatment. Our findings suggest that AR can impair academic achievement, emphasizing the importance of regular follow-up, symptom control, and appropriate treatment to maintain school success.

Previous studies have shown a higher prevalence of ADHD symptoms in children with allergic diseases. Lin et al. reported a significant association between AR and ADHD in 9–10-year-olds with AR, asthma, and atopic dermatitis [22]. Consistently, our study found higher AD and hyperactivity CPRS scores during GPS compared with both NGPS and controls, supporting a link between AR and ADHD and underscoring the neurobehavioral impact of seasonal allergen exposure.

Our study showed significantly higher AD and hyperactivity scores in AR patients during GPS than NGPS and controls, suggesting pollen exposure contributes to these symptoms. In contrast, Lee et al. reported increased inattention but no difference in hyperactivity/impulsivity, attributing this to nasal symptoms impairing attention [23]. By contrast, our data showed a clear increase in hyperactivity during GPS, suggesting that seasonal variations in AR may influence hyperactivity. This discrepancy may reflect differences in age, assessment methods, or environmental factors. Overall, AR should be considered not only for its physical but also neurobehavioral effects, underscoring the impact of seasonal changes on ADHD symptoms.

ADHD is known to be more prevalent in males [24]. In our study, an analysis of CPRS scores by sex revealed that both male and female patients had significantly higher scores during GPS compared to NGPS. While AD scores in girls during GPS were similar to those of the control group, boys had significantly higher AD and hyperactivity scores than controls. However, in NGPS, no significant differences were observed in AD or hyperactivity scores between male or female AR patients and the control group. This finding suggests that during periods of reduced pollen exposure, children with AR may exhibit a risk profile for ADHD similar to that of children without a known neurobehavioral disorder, further supporting the impact of seasonal allergen exposure on neurobehavioral symptoms.

Hyperactivity, among the ADHD subtypes, is known to be more prevalent in early childhood (preschool and primary school years) and tends to decline with age [24]. In a study by Lin et al. involving children aged 9–10 years with allergic diseases, hyperactivity was found to be more prevalent than AD in AR patients [22]. Similarly, our study showed that hyperactivity scores in AR patients were significantly higher than those in the control group during both GPS and NGPS. Additionally, median hyperactivity scores were higher compared to other ADHD subgroups. These findings suggest that in children aged 6–12 years, hyperactivity may be more common than other ADHD subtypes, regardless of AR.

In AR, nasal symptoms may occur alone or with ocular symptoms [25]. Cao et al. reported a higher ADHD prevalence in patients with nasal symptoms only than in those with both nasal and ocular symptoms [26]. Conversely, Chen et al. found greater ADHD risk in patients with both nasal and ocular symptoms [6]. In our study, patients with rhinoconjunctivitis showed significantly higher hyperactivity and total CPRS scores than those with nasal symptoms alone. The discrepancies in the literature may be attributed to variations in geographic regions, study periods, and differences in treatment regimens.

Our study identified male sex, high nasal VAS scores, and snoring as independent risk factors for AD during GPS. The association with male sex aligns with previous research, including

Tsai et al. [27]. The link between high nasal VAS scores and AD suggests that AR-related nasal symptoms impair concentration, consistent with studies showing that nasal congestion and sleep disturbances contribute to cognitive dysfunction in children [4]. Snoring is a recognized indicator of upper airway obstruction during sleep [28], and prior studies have associated it with AD and learning difficulties due to sleep fragmentation and oxygen desaturation [29,30]. However, otolaryngologic evaluation was not performed; therefore, further studies with objective assessments are needed to clarify the causal link between snoring and neurocognitive impairment. These findings emphasize that the association between snoring, nasal congestion, and AD highlights the crucial role of overall health, not only in maintaining physical well-being but also in supporting cognitive development and academic performance. Furthermore, the identification of ocular symptoms as a significant factor in hyperactivity suggests that AR should be approached with a multidisciplinary perspective. Early diagnosis and appropriate treatment may play a supportive role in alleviating attention and behavioral issues in children with AR.

Our study makes an important contribution by evaluating the association between AR and ADHD within the context of seasonal variation, considering the limited number of investigations in this field. One of its major strengths is the prospective design, which enabled a structured and time-sensitive assessment of symptom changes. Furthermore, rather than treating AR and ADHD as a single entity, our analysis of subgroups and sex differences allowed for more nuanced and comprehensive findings. The inclusion of an age- and sex-matched control group further enhanced the reliability and interpretability of the results. In light of recent evidence syntheses that are predominantly diagnosis-based and do not include seasonal or repeated symptom-scale assessments [8,9], our study advances the literature by conducting repeated, symptom-scale assessments across GPS and NGPS in a homogeneous cohort of grass pollen–sensitized children and by comparing these findings with a control group. Beyond demonstrating the coexistence of AR and ADHD, we also identified independent associations of high nasal symptom burden, snoring, and male sex with AD, as well as ocular symptom burden with hyperactivity, thereby shedding light on potential underlying mechanisms. Collectively, our findings move beyond prior diagnosis- or registry-based reports, offering a seasonally structured, symptom-scale, and functionally oriented perspective that complements and extends existing evidence.

Despite these strengths, several limitations of our study should be acknowledged. A key limitation of our study is that the ADHD assessment relied solely on the parent-reported CPRS, which raises the possibility of reporting bias since caregivers were aware of both the AR diagnosis and the timing of assessments (GPS vs. NGPS). For a more comprehensive evaluation, future studies should incorporate additional assessment tools and include teacher-based reports to better understand the relationship between AR and ADHD. Second, the control group completed the CPRS only once and without seasonal classification. Consequently, seasonal and contextual factors—such as end-of-year school routines or increased outdoor activity—may have influenced CPRS ratings independent of allergic symptoms. This residual confounding cannot be excluded and should be addressed in future longitudinal studies, including controls assessed in both GPS and NGPS. Another limitation is that indoor household smoke exposure, an important non-allergic trigger that may aggravate rhinitis symptoms and potentially influence ADHD manifestations, was not assessed. Future studies should therefore include a systematic evaluation of this factor to avoid potential residual confounding. Finally, our study did not assess polysensitization to other seasonal or perennial aeroallergens. Such sensitization may lead to longer periods of allergen exposure, which could contribute to more severe ADHD symptoms. Future studies should explore this potential association.

Conclusion

Our study demonstrates that AD and hyperactivity increase in AR patients during GPS, contributing to reduced academic performance and greater absenteeism. Male sex, high nasal VAS scores, and snoring were independent risk factors for AD, while high ocular VAS scores predicted hyperactivity. These findings suggest that AR severity exacerbates neurobehavioral manifestations and that seasonal allergen exposure, particularly in boys, may further amplify these symptoms. By emphasizing the impact of seasonal variations on cognition, this study highlights the importance of early diagnosis, regular follow-up, and individualized treatment in children with coexisting AR and ADHD. Multidisciplinary strategies that account for seasonal variability may improve both academic performance and quality of life.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

All authors made significant contributions to the study conception and design. Material preparation, data collection, and analysis were conducted by ASö, ASe, CG, and ZŞE. The first draft of the manuscript was written by ASö, ASe, CG, and ZŞE, and all authors critically reviewed, provided intellectual input, and revised the manuscript to enhance its scientific quality. EC and EDM contributed to the interpretation of the findings and the

finalization of the manuscript. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work. The authors certify that they have (collectively) personally written at least 90 percent of the manuscript.

Ethics approval

It was approved by the Ankara Bilkent City Hospital Clinical Trials Board and conducted following the ethical principles of the Declaration of Helsinki.

Consent to participate

Written informed consent was obtained from the parents of all participants included in the study.

Consent to publish

Written informed consent for publication was obtained from the parents of all participants included in the study.

Abbreviations

AD: Attention Deficit; ADHD: Attention Deficit Hyperactivity Disorder; AR: Allergic Rhinitis; ARIA: Allergic Rhinitis and its Impact on Asthma; CD: Conduct disorder; CPRS: Conners Parent Rating Scale; GINA: Global Initiative for Asthma; GPA: Grass Pollen Allergy; GPS: Grass Pollen Season; IgE: Immunoglobulin E; NGPS: Non-grass Pollen Season; ODB: Oppositional defiant behavior; SCORAD: Scoring Atopic Dermatitis; sIgE: Specific Immunoglobulin E; SPT: Skin Prick Test; VAS: Visual Analog Scale

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Rhinology 64: 2, 0 - 0, 2026
https://doi.org/10.4193/Rhin25.185

Received for publication:
April 4, 2025
Accepted: October 17, 2025

Associate Editor:
Michael Soyka

This manuscript contains online supplementary material

SUPPLEMENTARY MATERIAL

Table S1. Comparison of Conners parent rating scale scores between males and females in grass pollen season, non-grass pollen season, and the control group.

		Grass Pollen Season (Median, IQR)	Non-Grass Pollen Season (Median, IQR)	Control (Median, IQR)	p1	p2	p3
Attention Deficit	**Male**	3 (1-5)	2 (1-4)	2 (0-3)	**<0.001**	**<0.001**	0.197
	Female	2 (1-3)	2 (0,5-2)	1 (1-3)	**0.002**	0.191	0.735
Hyperactivity	**Male**	4 (1-7)	3 (1-6)	2 (0-4)	**<0.001**	**0.002**	0.069
	Female	3 (1-6)	2 (1-4)	2 (0-3)	**<0.001**	**0.005**	0.413
Oppositional Defiance	**Male**	2 (0-4)	2 (0-4)	2 (0-5)	**0.046**	0.752	0.425
	Female	2 (0-2,5)	1 (0-2)	1 (0-3)	**0.043**	0.551	0.697
Conduct Disorder	**Male**	2 (1-4)	2 (1-4)	3 (1-6)	**0.030**	0.325	0.182
	Female	2 (1-3,5)	2 (0,5-3)	1 (0-4)	**0.080**	0.629	0.752
Total CPRS Score	**Male**	13 (6-18)	9,5 (4-15)	10 (4-19)	**<0.001**	0.114	0.870
	Female	9 (4,5-13,5)	7,5 (3,5-10)	7 (3-11)	**<0.001**	0.093	0.793

p1: Comparison between patients during the grass pollen season and patients during the non-grass pollen season; p2: Comparison between patients during the grass pollen season and the control group; p3: Comparison between patients during the non-grass pollen season and the control group; CPRS: Conners Parent Rating Scale, IQR: Interquartile Range.