Early Online

The European Research Journal 2025 Original Article

DOI: https://doi.org/10.18621/eurj.1708291 *Pediatric Immunology and Allergic Diseases*

Unmasking hidden deficits: Language, cognitive, and mathematical challenges in children with allergic rhinitis

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ABSTRACT

Objectives: Children with allergic rhinitis are known to exhibit atypical developmental patterns and may face difficulties in language, speech, cognitive, and academic skills. This study aims to compare children newly diagnosed with allergic rhinitis (ages 6-9) with their typically developing peers in terms of language development, cognitive performance, and mathematical skills.

Methods: A total of 70 participants were included in the study, comprising 35 children with newly diagnosed allergic rhinitis and 35 healthy controls. Following the collection of sociodemographic data, participants were assessed using the Test of Language Development Primary-Fourth Edition: Turkish Version (TOLDP-4:T), the Wechsler Intelligence Scale for Children-Revised (WISC-R), and a set of age-appropriate non-routine mathematical problems.

Results: According to the TOLDP-4:T results, children in the allergic rhinitis group demonstrated below-average performance in listening, organizing, grammar, and over all language skills, whereas their healthy peers performed at an average level. In the WISC-R assessment, the allergic rhinitis group had significantly lower mean scores compared to the control group. While a significant correlation between verbal IQ scoress and mathematical performance was initially found, this relationship was no longer statistically significant after applying the Bonferroni correction.

Conclusions: Allergic rhinitis appears to have a negative impact on children's language development, cognitive abilities, and mathematical performance. These findings highlight the importance of early identification and intervention for children with allergic rhinitis to support their developmental outcomes.

Keywords: Allergic rhinitis, language impairment, cognition, mathematics

Allergic rhinitis is a condition characterized by inflammation of the nasal mucosa following exposure to allergens. This condition significantly reduces the quality of life, impacts productivity, restricts daily activities, and increases the risk of developing related conditions such as sinusitis, middle ear infections, and asthma1. The degranulation of mast cells mediated by immunoglobulin E (IgE) can trigger common symptoms including nasal discharge, itching, sneezing, and nasal congestion. Additionally, less common symptoms may include itching in the palate, ears, and throat, headaches, fatigue, diminished sense

Received: May 28, 2025 **Accepted:** July 18, 2025 **Available Online:** July 22, 2025 **Published:** XX XX, 2025

How to cite this article: Savaş M, Emrah Gİ, Dilek F, Kahraman Beğen S. Unmasking hidden deficits: Language, cognitive, and mathematical challenges in children with allergic rhinitis. Eur Res J. 2025. doi: 10.18621/eurj.1708291

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of smell, and a sensation of fullness in the ears when exposed to allergens [1, 2].

In pediatric patients, the common symptoms of allergic rhinitis encompass cough, sneezing, nasal itching, nasal congestion, sore throat, recurrent infections, halitosis, shortness of breath, hypernasal speech, and behavioral issues [3]. Symptoms such as nasal discharge, nasal itching, and sneezing can lead to school absenteeism, hinder participation in sports, and result in social withdrawal. This can create learning difficulties in children struggling to concentrate. Additionally, nasal congestion can negatively affect sleep quality, further reducing overall quality of life. Research indicates that 80% of individuals with hay fever experience fatigue, with 36% potentially facing depressive symptoms [4].

Allergic Rhinitis and Speech and Language Disorders

Despite the significance of allergic conditions, research exploring their effects on language and speech development in childhood is limited. A recent cross-sectional study involving 639 children with language and speech delays revealed a higher prevalence of allergic symptoms among these children, prompting inquiries into the potential link between allergic conditions and language skills [5]. Given that children with allergic rhinitis may experience allergic inflammation, sleep disturbances, school absenteeism, learning difficulties, and attention deficits, it is plausible that the risk of developing language and speech disorders could be heightened [6].

Allergic Rhinitis and Cognitive Disorders

Beyond the immediate physical symptoms, allergic rhinitis can give rise to psychosocial and cognitive disorders. Studies have demonstrated that individuals with allergic rhinitis may exhibit impaired learning and comprehension abilities. Specifically, patients experiencing intermittent allergic rhinitis in allergen-laden seasons have shown poorer performance in learning and memory assessments compared to healthy controls [7]. Notably, cognitive functions and decision-making skills have been found to improve significantly during periods devoid of allergen exposure [8].

The Relationship Between Language and Mathematical Performance

The interconnections among linguistic, symbolic, and visual representations of mathematical knowledge are multifaceted. These relationships evolve throughout the educational process and continue to develop thereafter [9]. In educational settings, the enhancement of speaking, reading, and writing skills is particularly emphasized within the context of mathematical language. This linguistic foundation plays a crucial role in students' ability to demonstrate knowledge in various contexts, such as standardized tests that frequently contain complex word problems [10]. Moreover, students are often required to articulate their problem-solving strategies in detail.

Albayrak and Erkal [11] noted that one of the primary contributors to failure in mathematics is linked to the level of proficiency achieved in Turkish language classes. Their observations of 535 students indicated that those who excelled in Turkish also tended to perform well in mathematics. The effective development of reading comprehension and expression skills in Turkish positively correlates with success in mathematics, underscoring that proficiency in both subjects mutually supports academic achievement [11].

The Relationship Between Cognition and Mathematical Performance

Higher-order cognitive skills are vital for the development of mathematical abilities. These skills encompass the capacity to understand the processes involved in problem-solving, including recognizing errors and adapting methods. Individuals with strong higher-order cognitive skills can analyze problems and identify areas needing improvement [12]. Research indicates that higher-order cognitive skills can be cultivated over time [13].

Working memory serves as a central cognitive system that facilitates cognitive processes by maintaining information actively in mind. This capacity undergoes significant developmental changes, increasing in both capacity and processing speed from childhood through adolescence [14]. Research has established a strong correlation between working memory and mathematical success; children with lower working memory capacity generally demonstrate poorer performance in mathematics [15, 16]. Kyttälä and Lehto [15] emphasize that children with lower memory capacity relative to their peers may also exhibit weakened mathematical abilities.

METHODS

The present study is cross-sectional, utilizing scales and tests administered during face-to-face interviews to assess language, cognitive, and mathematical skills in children aged 6 to 8 years with chronic allergic rhinitis and typical development.

Participants

Inclusion criteria for the research group included being aged between 6 and 8.11 years, obtaining parental consent for participation, lacking a diagnosis of primary neurological or psychiatric illness, having no mental or motor developmental delays, and have been diagnosed with allergic rhinitis for the first time. Inclusion criterias were identical for the control group, with the exception of the absence of allergic rhinitis diagnosis. A total of 35 children with newly diagnosed with allergic rhinitis and 35 typically developing children matched for age and sex were included in the study.

Data Collection and Analysis

Data were collected through the face-to-face application of the TOLDP-4:T, WISC-R, and age-appropriate non-routine mathematical problems.

Data Collection Tools

WISC-R (Wechsler Intelligence Scale for Children)

Developed by Wechsler, this intelligence test is specifically designed for children. It serves as a clinical measurement tool for evaluating cognitive abilities in children aged 6 to 16 years. The test comprises two main sections: one assessing verbal abilities and the other performance abilities, with each section containing six subtests. The verbal subtests include "Information, Similarities, Arithmetic, Comprehension, and Digit Span", while the performance subtests consist of Picture Completion, Picture Arrangement, Block Design, Object Assembly, and Coding. The verbal subtests assess the child's verbal understanding and comprehension, while the performance subtests evaluate cognitive activities requiring perceptual organization [17].

TOLDP-4: T (Test of Language Development Primary-Fourth Edition: Turkish Version)

This is the Turkish adaptation of the Test of Language Development, designed for children aged 4 to 8 years and 11 months. Adapted into Turkish by Topbaş and Güven [18], TOLDP-4: T is a norm-referenced standardized test aimed at assessing various aspects of language development. It includes six main subtests: Picture Vocabulary (PV), Relational Vocabulary (RV), Oral Vocabulary (OV), Syntactic Understanding (SU), Sentence Imitation (SI), and Morphological Completion (MC). The raw scores from these core subtests are converted into standard scores for analysis, allowing for the categorization of language development levels. Composite performances such as listening (PV + SU), organizing (RV + SI), speaking (OV + MC), grammar (SU + SI + MC), semantics (PV + RV + OV), and over all language ability (PV + RV + OV + SU + SI + MC) are also calculated [18].

Non-Routine Mathematical Problems

It consists of 9 verbal problems developed to examine the non-routine mathematical problem solving performance of primary school children in Turkey. The 9 word problems developed for 6-7 year old children are accompanied by balls, cups, abacus, sticks, balls of various sizes, paper and pencils to model the operations of separation, multiplication, addition, division by grouping, division by sharing, and division by remainder [19]. For 8-9 year old children, 9 verbal problems were presented that included five basic strategies (working backwards, estimation and control, systematic list making, drawing a figure, looking for correlations) among the basic strategies related to problem solving, and appropriate materials were provided for modeling. There is no time limit for the solution for both age groups. There is no need for 4 basic artimetic operations (addition, subtraction, multiplication, division) skills for solving the problems. The solution can be reached by modeling or other reasoning processes without activating the 4 operations. Reaching the correct solution of the problem is scored as 1; not reaching the correct solution is scored as 0.

Data Collection Procedure

All assessments were carried out face-to-face in a quiet environment. In addition to the TOLDP-4:T and WISC-R applications, age-appropriate non-routine mathematical problems were presented to the children, who were expected to answer after receiving necessary explanations. Appropriate materials (e.g., beans, beads, containers) were provided for the mathematical

Table 1. Demographic information of participants

Group		Allergic rhinitis			Healthy controls		
Variables		n	Percentage (%)	Mean±SD	n	Percentage (%)	Mean±SD
Gender	**Male**	21	60		23	65.7	
	Female	14	40		12	34.3	
Age (years)	**6-6.11**	14	40	6.86±0.81	11	31.4	6.97±0.79
	7-7.11	12	34.3		14	40	
	8-8.11	9	25.7		10	28.6	
Class	**Grade 1**	20	57.1		19	54.3	
	Grade 2	9	25.7		10	28.6	
	Grade 3	6	17.1		6	17.1	

SD=Standard Deviation

problems aimed at six-year-old children. The data collection process for each child varied based on their performance, averaging 2-3 hours, with breaks provided at half-hour intervals. All tests were administered in two sessions to ensure completion.

This study was approved by the Istanbul Atlas University Non-Interventional Scientific Research Ethics Committee (Decision no.: 2024-06/16, date: 22.07.2024). Informed consent was obtained from all participants.

Statistical Analysis

Statistical analyses were conducted using the SPSS Vs 26.0 software package (SPSS Inc., Chicago, IL, USA). The normality of the data was evaluated using the Shapiro-Wilk test, accepting a significance level of $P>0.05$. Descriptive statistics included mean, standard deviation (Mean±SD), minimum and maximum values, frequencies, and percentages. Due to significant deviations from normal distribution, the Mann Whitney U test, a non-parametric technique, was employed for inter-group comparisons. Correlation analyses were conducted using the Spearman correlation test. A $P<0.05$ value was considered statistically significant in all analyses.

Table 2. Results of intergroup comparison of TOLDP-4: T levels

TOLDP-4: T	Group	n	Minimum	Maximum	Mean±SD	P value
Listening	**Healthy controls**	35	1.00	6.00	3.69±1.16	**0.001***
	Allergic rhinitis	35	1.00	4.00	2.86±1.00	
Organizing	**Healthy controls**	35	1.00	5.00	2.86±1.17	**0.019***
	Allergic rhinitis	35	1.00	4.00	2.20±1.08	
Speaking	**Healthy controls**	35	1.00	6.00	3.23±1.21	**0.001***
	Allergic rhinitis	35	1.00	4.00	2.26±1.12	
Grammar	**Healthy controls**	35	1.00	5.00	3.11±1.08	**0.013***
	Allergic rhinitis	35	1.00	4.00	2.51±0.89	
Semantics	**Healthy controls**	35	2.00	6.00	3.66±0.94	**0.001***
	Allergic rhinitis	35	1.00	4.00	2.80±1.02	
Overall language ability	**Healthy controls**	35	1.00	5.00	3.17±1.20	**0.005***
	Allergic rhinitis	35	1.00	4.00	2.34±1.16	

TOLDP-4: T= Test of Language Development Primary-Fourth Edition: Turkish Version, SD=Standard Deviation
*P<0.05, Mann Whitney U Test

RESULTS

A total of 70 participants were included in the study, comprising 35 individuals with allergic rhinitis and 35 healthy control subjects. The variables of the participants, such as gender, age, and the level of education they are enrolled in, are presented in Table 1.

In the allergic rhinitis group, 60% of the participants were male and 40% were female, while 65.7% were male and 34.3% were female in the healthy control group. In terms of age distribution, 40% of the allergic rhinitis group was 6-6.11 years old, 34.3% was 7-7.11 years old and 25.7% was 8-8.11 years old; in the healthy control group, 31.4% was 6-6.11 years old, 40% was 7-7.11 years old and 28.6% was 8-8.11 years old. The mean age was 6.86±0.81 years in the allergic rhinitis group and 6.97±0.79 years in the healthy control group. In terms of grade distribution, first graders

Table 3. Results of intergroup comparison of WISC-R scores

WISC-R	Group	n	Minimum	Maximum	Mean±SD	P value
Information	**Healthy controls**	35	5.00	15.00	10.29±2.70	**<0.001***
	Allergic rhinitis	35	6.00	9.00	7.66±0.80	
Similarities	**Healthy controls**	35	6.00	18.00	12.17±3.08	**<0.001***
	Allergic rhinitis	35	6.00	10.00	7.74±1.07	
Arithmetic	**Healthy controls**	35	6.00	15.00	10.83±2.57	**<0.001***
	Allergic rhinitis	35	4.00	10.00	7.66±1.33	
Vocabulary	**Healthy controls**	35	7.00	16.00	9.71±2.01	**<0.001***
	Allergic rhinitis	35	4.00	8.00	6.46±1.54	
Comprehension	**Healthy controls**	35	0.00	17.00	8.80±4.57	**0.002***
	Allergic rhinitis	35	0.00	8.00	5.60±2.14	
Picture completion	**Healthy controls**	35	4.00	14.00	8.26±2.79	**<0.001***
	Allergic rhinitis	35	4.00	7.00	5.37±1.14	
Picture arrangement	**Healthy controls**	35	3.00	18.00	12.20±3.73	**<0.001***
	Allergic rhinitis	35	4.00	7.00	5.09±0.92	
Block design	**Healthy controls**	35	8.00	19.00	14.20±3.78	**<0.001***
	Allergic rhinitis	35	5.00	8.00	6.63±0.94	
Object assembly	**Healthy controls**	35	8.00	19.00	12.77±2.67	**<0.001***
	Allergic rhinitis	35	0.00	4.00	3.89±0.68	
Coding	**Healthy controls**	35	7.00	19.00	13.63±3.38	0.057
	Allergic rhinitis	35	7.00	15.00	11.97±1.40	
Verbal IQ scores	**Healthy controls**	35	77.00	133.00	101.97±14.18	**<0.001***
	Allergic rhinitis	35	72.00	89.00	79.26±4.58	
Performance IQ score	**Healthy controls**	35	94.00	150.00	116.20±14.63	**<0.001***
	Allergic rhinitis	35	70.00	86.00	75.23±3.96	
Total IQ score	**Healthy controls**	35	86.00	136.00	109.91±14.60	**<0.001***
	Allergic rhinitis	35	68.00	80.00	75.40±3.52	

WISC-R=Wechsler Intelligence Scale for Children-Revised, SD=Standard Deviation
*P<0.05, Mann Whitney U Test

constituted the largest group in both groups (57.1% and 54.3%). Descriptive statistics findings related to the general questions asked to the participants are given in Table 2. Comparison findings of the participants' TOLDP-4: T levels are given in Table 2.

A statistically significant difference was found between the healthy control and allergic rhinitis groups across all skill domains (P<0.05). In the healthy control group, the mean scores for listening (3.69±1.16), organizing (2.86±1.17), speaking (3.23±1.21), grammar (3.11±1.08), semantics (3.66±0.94), and overall language ability (3.17±1.20) were higher compared to the allergic rhinitis group. In the allergic rhinitis group, the corresponding mean scores were 2.86 ±1.00 for listening, 2.20±1.08 for organizing, 2.26±1.12 for speaking, 2.51±0.89 for grammar, 2.80±1.02 for semantics, and 2.34±1.16 for overall language ability. The intergroup comparison findings of WISC-R test scores are presented in Table 3.

In the healthy control group, scores for information, similarities, arithmetic, vocabulary, comprehension, picture completion, picture organization, block design, object assembly, verbal IQ, performance IQ, and overall IQ were significantly higher than in the allergic rhinitis group (P<0.05). No significant difference was found in the coding score (P=0.057). Comparison of math scores is presented in Table 4.

The mean score was 2.63±1.31 in the healthy control group and 1.06±0.94 in the allergic rhinitis group and the difference between the groups was statistically significant (P=0.000). The relationship between WISC-R scores and math performance was examined by Spearman correlation analysis. The findings are presented in Table 5.

In the correlation tests conducted between mathematics performance and WISC-R subtests. while there was a moderate positive significant relationship between only verbal IQ scores and mathematics performance before correction (r=0.405, P=0.016), no statistically significant relationship was found between any variable and mathematics performance after Bonferroni correction. According to the correlation analysis, no significant relationship was found between mathematics performance and TOLDP-4:T levels with any variable.

DISCUSSION

This study investigates the language, cognitive, and mathematical performance of children aged 6 to 8.11 years diagnosed with chronic allergic rhinitis. A total of 70 participants, comprising 35 children with newly diagnosed allergic rhinitis and 35 typically developing peers, were assessed using the Test of Language Development Primary-Fourth Edition: Turkish Version (TOLDP-4:T), the Wechsler Intelligence Scale for Children-Revised (WISC-R), and Non-Routine Mathematical Problems.

Chronic allergic rhinitis is a prevalent health condition that can significantly impair the quality of life of affected individuals [20]. The symptoms associated with this condition, including nasal congestion, sneezing, and itching, often hinder the ability to concentrate, which may detrimentally affect academic performance [21]. Difficulties in reading and writing can ensue, contributing to attention deficits and subsequent learning challenges. Research has documented that children with allergic rhinitis may struggle to engage fully in classroom activities, or may exhibit diminished concentration during participation [22]. Such challenges can adversely impact academic success and limit future educational and career opportunities.

Comparison of TOLDP-4:T scores revealed statistically significant differences across all skill levels between the groups. Specifically, the allergic rhinitis group exhibited lower composite scores in listening, organizing, grammar, speaking, and comprehension, indicating potential delays in language development. The physical symptoms of allergic rhinitis, particularly nasal congestion, can distract individuals from verbal

Table 4. Results of intergroup comparison of mathematics scores

Group	n	Minimum	Maximum	Mean±SD		P value
Healthy controls	35	0.00	5.00	2.63	1.31	**<0.001***
Allergic rhinitis	35	0.00	3.00	1.06	0.94	

SD=Standard Deviation
*P<0.05, Mann Whitney U Test

Table 5. The relationship between WISC-R & TOLDP-4: T and mathematics performance

WISC-R		Math performance	TOLDP-4: T		Math Performance
Information	r	0.154	**Listening**	**r**	-0.223
	P value	0.377		**P value**	0.197
Similarities	r	0.119	**Organizing**	**r**	0.104
	P value	0.497		**P value**	0.551
Arithmetic	r	0.105	**Speaking**	**r**	0.234
	P value	0.547		**P value**	0.176
Vocabulary	r	0.232	**Grammar**	**r**	0.066
	P value	0.181		**P value**	0.705
Comprehension	r	0.168	**Semantic**	**r**	0.115
	P value	0.336		**P value**	0.509
Picture completion	r	0.242	**Overall language ability**	**r**	0.127
	P value	0.162		**P value**	0.468
Picture arrangement	r	0.127			
	P value	0.467			
Block design	r	0.157			
	P value	0.367			
Object assembly	r	-0.009			
	P value	0.959			
Coding	r	-0.075			
	P value	0.667			
Verbal IQ scores	r	0.405*			
	P value	0.016			
Performance IQ score	r	0.235			
	P value	0.175			
Total IQ score	r	0.321			
	P value	0.060			

TOLDP-4: T=Test of Language Development Primary-Fourth Edition: Turkish Version, WISC-R=Wechsler Intelligence Scale for Children-Revised, SD=Standard Deviation, r=Correlation Coefficient, Math=Mathematics

*P<0.05/13≈0.0038, Spearman Correlation Analysis

communication and comprehension, leading to compromised listening abilities [23]. Furthermore, persistent nasal congestion may interfere with sound transmission, thereby impairing verbal communication [24]. These deficits in language and communication skills can also limit social interactions, as difficulties in expressing oneself may lead to social isolation [25]. The critical role of language in educational contexts underscores the importance of addressing these challenges to promote academic success.

Analysis of WISC-R scores similarly indicated significant disparities between the groups, with the allergic rhinitis participants scoring lower in multiple subtests, including general intelligence, similarities, arithmetic, vocabulary, comprehension, and performance IQ scores. The similarities subtest evaluates verbal abstract thinking and the ability to analyze relationships, which are essential for cognitive processing [17, 26]. The arithmetic subtest, which assesses mathematical skills and cognitive processes

such as attention and memory, further illustrates the cognitive implications of allergic rhinitis [17, 26]. The block design subtest evaluates visual-spatial abilities and perceptual motor skills, which may also be compromised by the inflammatory effects of allergic rhinitis on brain function [7]. Various studies have linked allergic rhinitis in children to attention deficits and learning difficulties, further corroborating the notion that this condition adversely affects cognitive functioning. The observed patterns suggest that the cognitive impairments associated with allergic rhinitis may be exacerbated by sleep disturbances and daytime fatigue [27]. Effective management of allergic rhinitis could potentially enhance cognitive functions and academic outcomes, highlighting the need for integrated treatment approaches that include cognitive development support [28]. The inflammatory processes associated with allergic rhinitis may underlie the cognitive difficulties observed in this population [28].

In terms of performance on non-routine mathematical problems, the healthy control group outperformed the allergic rhinitis group, suggesting that allergic rhinitis may impair cognitive functions and attention necessary for problem-solving. Existing literature supports the detrimental effects of allergic rhinitis on cognitive performance, particularly in relation to attention and memory [28].

The correlation analysis between WISC-R scores and mathematical performance yielded a significant relationship between verbal IQ scoress and mathematical performance prior to correction for multiple comparisons. However, following Bonferroni correction, no statistically significant relationships were found between mathematical performance and any of the tested variables. This finding aligns with research suggesting that children's mathematical performance is influenced by a combination of cognitive abilities and social-emotional factors [29]. Health challenges, such as allergies, may elevate stress levels in children, further negatively impacting academic success.

Limitations

This study provides valuable insights into the language, cognitive, and mathematical challenges faced by children with allergic rhinitis; however, several limitations must be acknowledged. First, the relatively small sample size (n=70) may limit the generalizability of the findings to the broader pediatric population. Larger-scale studies would enhance statistical power and allow for subgroup analyses based on variables such as symptom severity or allergy duration. Second, detailed clinical data such as duration of allergic symptoms, comorbid conditions, medication use, and history of medical treatment were not collected, which may have influenced the observed cognitive and academic outcomes. Additionally, the study did not include follow-up assessments to examine whether the observed deficits persist over time or respond to medical and/or educational interventions. Lastly, environmental and psychosocial factors that may affect developmental outcomes - such as socioeconomic status, parental education, and sleep quality - were not controlled for, which could have acted as confounding variables. Future research addressing these factors is necessary to better understand the long-term developmental impacts of allergic rhinitis in childhood.

CONCLUSION

This study highlights the poorer performance of children with allergic rhinitis in language development, as indicated by TOLDP-4:T scores, and cognitive functioning as assessed by WISC-R. The significant differences in general intelligence and cognitive abilities between the two groups underscore the adverse impact of allergic rhinitis on cognitive functions. To address these challenges, it is crucial to conduct thorough evaluations of potential difficulties in language, cognitive, and academic domains alongside medical treatment for allergic rhinitis. The integration of behavioral and psychosocial interventions may further support the development of affected children.

Ethical Statement

This study was approved by the Istanbul Atlas University Non-Interventional Scientific Research Ethics Committee (Decision no.: 2024-06/16, date: 22.07.2024). . Informed consent was obtained from all participants.

Authors' Contribution

Study Conception: MS, GİE; Study Design: MS, SKB; Supervision: MS, FD; Funding: N/A; Materials: GİE, FD; Data Collection and/or Processing: GİE, FD; Statistical Analysis and/or Data Interpretation: SKB,

MS; Literature Review: MS, GİE; Manuscript Preparation: MS, SKB; and Critical Review: MS, FD.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

Financing

The authors disclosed that they did not receive any grant during the conduction or writing of this study.

Generative Artificial Intelligence Statement

The author(s) declare that no artificial intelligence-based tools or applications were used during the preparation process of this manuscript. The all content of the study was produced by the author(s) in accordance with scientific research methods and academic ethical principles.

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