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REVIEW

The Prevalence, Clinical Picture, and Triggers of Allergic Rhinitis in Saudi Population: A Systematic Review and Meta-Analysis

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Objective: To summarize the current evidence regarding the prevalence of Allergic rhinitis (AR) and its symptoms, triggers, and impact on the quality of life of the Saudi population.

Methods: A Computerized Search in MEDLINE via PubMed, MEDLINE Core database, Scopus, and Web of Science was conducted using relevant keywords. A two-stage screening process, data extraction, and quality assessment were conducted by four independent reviewers. Comprehensive Meta-analysis was used for all statistical analyses (CMA; USA: version 3.3.070).

Results: Sixteen articles (n= 31,990 patients) were included. The overall estimated prevalence of AR was 21.2%, 95% CI (12.8–33.1%). Males had a higher prevalence of AR than females (31.7% vs 27.1%), although the difference was not significant (OR=1.24, 95% CI: 0.78–1.953; p=0.356). Children and adolescents exhibited a lower prevalence of AR than adults (13.7% vs 31.1%). Urban AR prevalence was much greater than rural (38.4% vs 13.0%). Asthma, atopic dermatitis, and eczema are all associated with AR. The most common signs and symptoms of AR were headache 33.9%, watery discharge 28.6%, sneezing 24.6%, itchy nose, runny nose 22.2%, nasal obstruction or congestion 22.0%, loss of smell 21.9%, and wheezing 17.2%. The most prevalent triggers of AR were perfume 36.8%, dust 27.3%, air conditioning 23.4%, weather or temperature changes 17.8%, air pollution 14.5%, drugs or chemicals 13.8%, tobacco 10.8%, atopy 10.3%, and insects 10.2%.

Conclusion: The overall prevalence of AR in Saudi Arabia is 21.2%. The prevalence of AR was comparable in both males and females. However, it was higher in adults than in children and adolescents, and in urban areas than rural areas. Asthma, atopic dermatitis, and eczema co-occurrence with AR are common. AR has a negative impact on the quality of life of the patients in the form of interference with daily activities, sleep problems, difficulty of breath, and school absenteeism.

Keywords: allergic rhinitis, Saudi Arabia, prevalence, meta-analysis

Introduction

Allergic rhinitis (AR) is a hypersensitivity reaction that occurs when inhaled particles contact the nasal mucosa and trigger an immunoglobulin E (IgE)-mediated inflammatory reaction.[1] Nasal blockage, rhinorrhea, sneezing, and nasal itching are among the most prevalent symptoms of AR.[2] Fatigue, irritability, cough, and postnasal drip are also present.[3] AR is influenced by a variety of elements, including environmental conditions, weather, and atopy. Seasonal allergens include spores of mildew and pollens from grasses and plants, whereas permanent allergens include home allergens, animal feces, mold, dust, and mites.[4] However, neither a single gene nor a single environmental element can explain AR's etiology.

The clinical symptoms of AR may be caused by a combination of many genes and particular environmental factors. AR is more likely to arise if there is a history of AR in the family.[5] In the lack of family history, the probability of having AR was estimated to be 13%. This risk increased to 29% if one parent or sibling had AR, to 47% if both parents had AR,

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and to 72% if both parents had similar atopic appearance.[6] A large number of genetic loci linked to an increased risk of AR have been determined using genetic linkage analysis.[7] Patients' socioeconomic status and quality of life are both affected negatively by the consequences of AR.[8] In many cases, AR is associated with asthma, eczema, and atopic dermatitis. Diagnosis and management of AR require a multistage approach, which increases the burden on individuals and healthcare systems.[9–11]

A recent systematic review and meta-analysis showed that the pooled prevalence of AR in America was 9%, 95% CI (3.5–55%), Europe 19%, 95% CI (1–44%), Africa 10%, 95% CI (3.6–23%), Asia 15%, 95% CI (1–48%), and Oceania 38%, 95% CI (19–48%).[12] However, Saudi Arabia was not included in the pooled analysis of Asia.

In Saudi Arabia and the Eastern Mediterranean region, there remains a limited number of epidemiological studies regarding the prevalence of AR.[13] The prevalence of rhinitis among children under the age of 15 years increased from 20% in 1986 to 25% in 1995, according to Al Frayh et al.[14] More than one-quarter of Saudi Arabian children between the ages of six and fifteen reported having symptoms of AR, according to another study.[15] Another study found that AR was reported in 12.7% of children between the ages of 4 and 16 years old.[16] In this systematic review and meta-analysis, we aimed to summarize the current evidence regarding the prevalence of AR and its symptoms, triggers, and impact on the quality of life of the Saudi population.

Methods

We have followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist and Cochrane handbook for systematic reviews of interventions in reporting this study.[17,18]

Eligibility Criteria

The used eligibility criteria were as follows (PECOs): Population: Studies that included data regarding Saudi patients; Exposure: AR and its associated factors; Comparator: Studies that compare between adults and children or report data for each separately; Outcomes: Studies reported data regarding the prevalence and incidence of AR; Study Design: Cross-sectional studies. We excluded case reports, conference abstracts, and non-English studies.

Information Sources and Search Strategy

On February 7, 2022, we have searched the following databases: MEDLINE via PubMed, MEDLINE Core database, Scopus, and Web of Science, using this search term "(Allergic rhinitis OR hay fever OR seasonal rhinitis OR perennial rhinitis) AND (Saudi Arabia OR Kingdom of Saudi Arabia OR Saudis Arabia OR Saudi Arab)" to identify the relevant citations. These databases were searched from inception to the date of search. Moreover, the reference lists of all included citations were searched. The retrieved citations were imported to EndNote X9 software and duplications were removed.

Selection Process

A screening sheet was developed using Microsoft Excel software. It contains the following information: Study ID, year of publication, title, abstract, keywords, DOI, and URL. Four independent reviewers conducted the selection process through a two-step screening approach. The first step was to screen the title and abstract of each study identified from the literature search to identify the studies that were eligible to be included in the second step (Full-text screening), where the reviewers read the full manuscript and decided if it fulfilled the eligibility criteria (included) or not (excluded). Any disagreement between the reviewers was solved by the judgment of the study supervisor.

Data Items and Collection Process

Four independent reviewers extracted the following data from the included studies to an offline pre-prepared Excel sheet: Demographic data of the included patients (Age, gender, education, marital status, economic status, and residency), study characteristics (used questionnaire, study duration, total sample size, city, and main findings), outcomes (prevalence of AR, the prevalence of associated allergic diseases, triggers of AR, symptoms of AR, and the impact of AR on the quality of life).

Risk of Bias and Quality Assessment

Using the National Institutes of Health (NIH) quality assessment tool for observational cohort and cross-sectional studies, two authors independently evaluated the risk of bias and the quality of each included article. Reviewers can critically evaluate the internal validity of research using this tool. Studies were deemed "good", "fair", or "poor". In the case when the authors disagreed on a rating, a third author resolved any disagreements.

Data Synthesis

The AR prevalence was calculated using the random-effects model with 95% CI. Using the I^2 statistic, we calculated the percentage of heterogeneity and inconsistency between studies, with values of 25%, 50%, and 75% deemed low, moderate, and high, respectively. The random-effect model was employed if the heterogeneity was considerable and $I^2 > 50\%$; otherwise, the fixed-effect model was utilized. Comprehensive Meta-analysis was used for all statistical analyses (CMA; USA: version 3.3.070). To resolve heterogeneity, sensitivity analysis was performed by removing one study in each scenario, which is known as sequential sensitivity analysis. Furthermore, subgroup analysis was performed to minimize the risk of inconsistency.

Publication Bias Assessment

Publication bias was assessed based on the criteria of Egger's test, and a funnel plot was generated for the forest plots that included 10 studies or more.

Results

Study Selection

Based on our literature search, we found a total of 404 relevant citations. After removing duplication, 260 articles underwent title/abstract screening. Then, 240 studies were deemed ineligible to our criteria. The full-text screening was performed on 20 articles, and only four studies were excluded. Finally, 16 articles (n= 31,990 patients) were included in the qualitative (systematic review) and quantitative synthesis (meta-analysis).[5,8,15,16,19–30] Figure 1 shows the PRISMA flow diagram of included studies.

Patients and Study Characteristics

All of the included studies were conducted in Saudi Arabia, except for Abdul Rahman et al, which was conducted in Egypt, Saudi Arabia, Lebanon, and United Arab Emirates.[30] The study duration of all included studies ranges from 1 month to 12 months. Eight studies used ISAAC questionnaire,[5,8,15,16,23,27–29] seven studies used self-administered, self-developed questionnaire,[19,20,22,24–26,30] and one study used interview questionnaire.[21] Regarding the age of the included population, seven studies included children and adolescents,[15,16,22,23,27–29] six studies included only adults,[5,8,20,21,25,26] and three studies included both children and adults.[19,24,30] The percentage of females in all studies was 47.14%. Table 1 summarizes the characteristics of included studies and patients.

Quality Assessment of Included Studies

Based on the NIH quality assessment tool for observational cohort and cross-sectional studies, about 62.5% of the studies were deemed as "Good", and 37.5% of the studies were deemed as "Fair". There were no "Poor" studies. All studies reported their objectives clearly and defined their population, except for Abdul Rahman et al, where the objectives were not clearly presented. Only five studies (31.25%) reported the response rate, and eight studies (50%) justified their sample size.

Meta-Analysis

The Overall Prevalence of AR

The pooled analysis of 15 studies showed that the overall estimated prevalence of AR was 21.2%, 95% CI (12.8–33.1%). The pooled data were heterogeneous (I^2=99.74%; p<0.001; Figure 2). Sensitivity analysis by removing one study in each

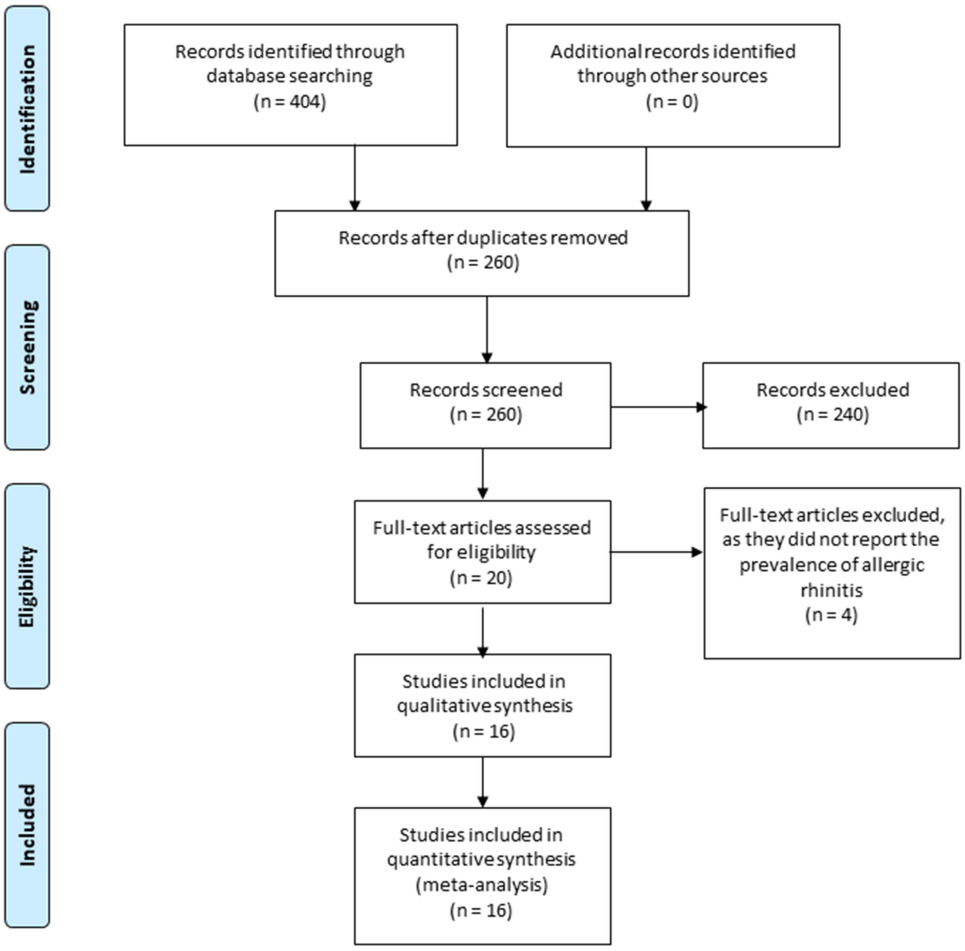

Figure 1 PRISMA flow diagram.

scenario demonstrated that no study affects the estimated prevalence (Figure 3); however, it could not solve the heterogeneity; therefore, subgroup analysis was performed. The funnel plot showed a risk of publication bias (Figure 4); however, egger's test demonstrated that this risk of bias was not significant (p=0.44).

Subgroup Analysis

The prevalence of AR was slightly higher in males vs females [31.7%, 95% CI (24.1–40.4%) vs 27.1%, 95% CI (18.8–37.3%)], respectively; however, there was no significant difference (OR=1.24, 95% CI: 0.78–1.953; p=0.356) (Figure 5). Regarding age, adults were associated with higher prevalence of AR compared to children and adolescents [31.1%, 95% CI (11.6–60.9%) vs 12.7%, 95% CI (7.50–20.7%)], respectively. Three studies reported prevalence of AR for both adults and children 36.5%, 95% CI (24.8–50.1%).

In terms of the geographical area, Central region was associated with higher prevalence 29.2%, 95% CI (6.20–72.0%), followed by the Northern region 23.0%, 95% CI (2.50–77.6%), the Western region 18.1%, 95% CI (0.90–84.2%), and the Southern region 13.7%, 95% CI (6.20–27.7%). Only one study reported prevalence for the Eastern region 48.0%, 95% CI (44.5–51.4%). The pooled analysis of three studies showed that the prevalence of AR in urban areas was considerably higher than in rural areas [38.4%, 95% CI (7.20–83.4%) vs 13.0%, 95% CI (9.20–17.9%)]. Two studies showed that the prevalence of AR in patients who presents with a family history of allergy in all of the family members was 40%, 95% CI (20.2–63.7%).

The prevalence of AR was comparable in both Summer and Winter 17.6%, 95% CI (9.10–31.1%) and 17.3%, 95% CI (10.2–27.8%), while the prevalence in the Spring and Autumn was much lower 6.00%, 95% CI (1.60–20.6%) and 5.20%,

Table 1 Summary of the Included Studies

Name	Study Design	City/Area	Study Duration	Study Tool	Total Sample	Prevalence of AR %	Age	Gender (Female n,%)	Inclusion Criteria	Main Finding
Alruwaili 2021[22]	Cross-sectional study	Arar city	12 months	Self-administered questionnaire (Arabic)	304	7.80%	From 15 years to 18 years	100%	All female secondary schoolsschools' students, aged between 15–18 years in Arar city	The reported prevalence of allergic rhinitis was 7.8% which was lower than most reported figures. Prevalence of allergic rhinitis can be reduced by effective preventive interventions such as raising awareness of the incidence of allergic disease and its risk factors and treatment options.
Almatroudi 2021[20]	Cross-sectional study	Qassim region	4 months	A self-administered questionnaire was developed based on three questionnaires for screening of respiratory allergies, namely the Asthma Control Questionnaire to measure asthma control in adults, the International Study of Asthma and Allergies in Childhood and the European Community Respiratory Health Survey asthma questionnaire	850	13.50%	From 18 years to 45 years and above 45 years	406 (47.8%)	Any adult individual (aged ≥ 18 years), who was literate to respond to an online questionnaire in English or Arabic and was living in the Qassim region	Prevalence The prevalence of respiratory allergies is varies from region to region in the KSA according to different studies. Gender and family history of respiratory allergy were found to have an association with the prevalence of respiratory allergies.
Alanazy 2021[21]	Cross-sectional study	Qassim region	12 months	Interview questionnaire	455	100%	From 20 years to 60 years and above 60 years	169 (37.1%)	Outpatients from the ENT clinic of King Saud Hospital in Unaizah city, Qassim region	Family history of AR and living in urban areas increase the risk of AR. Dust consider the most common trigger for AR, and oral histamine an intranasal steroids were the most frequent treatment used by AR patients. In clinical examination, inferior turbinate hypertrophy with pale bluish discoloration was the most common finding, and mild non-specific nasal symptoms are the most common presenting symptoms in AR patients.
Alqahtani 2020[8]	Cross-sectional study	Najran University, in southwestern Saudi Arabia	5 months	Interview questionnaire according to the ISASAC questionnaire	222	5%	21.5 ± 1.5 years	106 (47.747%)	Students in the health colleges of Najran University, in southwestern Saudi Arabia, during the period from January to May 2018.	Atopy and allergy disorders are common in Saudi young Saudi people, which is concerning. Comorbid allergic disorders were more common in their atopic disease group. The identification of allergen sensitization patterns in atopic illness patients is critical for developing effective preventative prevention and treatment methods.

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Table 1 (Continued).

Name	Study Design	City/Area	Study Duration	Study Tool	Total Sample	Prevalence of AR %	Age	Gender (Female n,%)	Inclusion Criteria	Main Finding
Al-Ghamdi 2020[5]	Cross-sectional study	Aseer region	NR	Arabic version of the validated ISAAC questionnaire	960	30.20%	Mean= 39.43 ± 14.63 years and a median of 36 years	255 (26.6%)	Adult Adults aged 20 years or older who attended any of the selected primary health care centers for any reason.	In the Aseer area, the prevalence of AR was shown to be higher in this study. During the management of AR, health policymakers, doctors, and healthcare professionals should examine the spread of the disorder and its related factors.
Mahnashi 2019[23]	Cross-sectional study	Jazan	3 months	Arabic version of the validated ISAAC questionnaire	1400	27.10%	Mean = 12.8 ± 1.456 years and a median of 13 years.	560 (40%)	Students in both level elementary and intermediate schools all over Jazan Region	Prevalence and severity of AR are significantly affected by living in urban or lowland areas and intermediate school education level.
Almehizia 2019[25]	Cross-sectional study	NR	6 months and 21 days	Self-report electronic survey	3458	82.40%	Mean= 29 ±10 years	1691 (59.4%)	Any adults who had at least one of the four signs of AR, ie, a watery runny nose, sneezing (violent/in bouts), nasal obstruction (inability to breath), itchy nose; watery/red itchy eyes, during the past year and not related to an episode of cold/flu	Dust is considered the most common trigger for AR. Other common triggers included pollen, mold, and fur. In Saudi Arabia, more than half of the AR patients had moderate to severe symptoms and an intermittent pattern of the disease pattern. Male gender, older age group, smoking, and chronic AR were all linked to pollen pollen-inducing AR. Mold-induced AR was linked to persistent forms of the illness, whereas AR produced by fur was linked to smoking. The female gender, younger age, smoking, and mild forms of the illness were all linked to AR caused by dust. Patients with AR are recommended to lose weight since they are more prone to develop the chronic forms of the illness if they are overweight.
Albaloushi 2019[24]	Cross-sectional study	Al-Ahssa	1 month	Self-report electronic survey	807	48%	From all age groups (under 15 years to above 55 years)	631 (78.2%)	Males and females from all age groups from Al-Ahssa, Saudi Arabia	Symptoms of AR are associated with living near farms and are usually triggered by dust. To improve the quality of life in AR cases, we need early recognition and diagnosis of the disease.

Alotaibi 2018[26]	Cross-sectional study	The University of Hail, Northern Saudi Arabia	NR	Self-report survey	1578	74%	NR (university students)	482 (30.5%)	Students in Hail University, Northern Saudi Arabia	AR is common among Hail University students, with a slightly larger male-to-female ratio. For better future control, more study is needed to identify the most common environmental and occupational allergens.
Alqahtani 2016[27]	Cross-sectional study	Najran Region, Southwestern Saudi Arabia	4 months	Modified ISAAC Phase III questionnaire	1700	6.30%	Mean= 12.2 ± 3.3	849 (49.9%)	Saudi school children in Najran Region, Southwestern Saudi Arabia	Asthma and other allergy illnesses are very common, which is concerning. The outcomes of this study highlight the need for multidisciplinary teams (pediatricians, immunologisimmunologistst, health educators, psychologists, social workers, rhinologistrhinologists, and dermatologists) to collaborate to regulate and reduce the burden of allergic disorders. To decrease morbidity and mortality due to under- or over-diagnosis, this program should involve the creation of school-based asthma clinics with facilities for proper diagnosis ofly diagnosing asthma in children. To raise knowledge of children allergy disorders, developing a comprehensive school-based asthma education program for allergic students, their parents, and school personnel should be explored. Developing a comprehensive school-based asthma education program for allergic students, parents, and school personnel should be explored to raise knowledge of children's allergy disorders. Meanwhile, determining allergen sensitization patterns in allergic patients will aid pediatricians in educating patients about environmental modification, as well as healthcare policy and decision-makers in selecting appropriate treatment strategies for asthma and other allergies, including allergen-specific immunotherapy when appropriate.
Al-Ghobain 2012[28]	Cross-sectional study	Riyadh, Saudi Arabia	NR	ISAAC questionnaire	3073	21.30%	From 16 years to 18 years	1569 (51.1%)	Secondary school students (16 to 18 years old) in Riyadh, Saudi Arabia	The most common age group associated with rhinitis in Saudi Arabia is 16 to 18 years old, and more common in females. A high frequency of asthma symptoms is linked to rhinitis symptoms.

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Table 1 (Continued).

Name	Study Design	City/Area	Study Duration	Study Tool	Total Sample	Prevalence of AR %	Age	Gender (Female n,%)	Inclusion Criteria	Main Finding
Nahhas 2012[29]	Cross-sectional study	Madinah	1 month	Arabic version of the validated ISAAC questionnaire	5188	4.20%	From 6 years to 9 years	1603 (30.9%)	Primary school students aged 6–8 years in Madinah	Over 40% of children in primary school-aged children in Madinah, Saudi Arabia, show symptoms suggestive of allergic disease prevalence within the first eight years of life, ranking among the highest in the world. More investigation is necessary to estimate the incidence of allergy issues in various locations of Saudi Arabia, among other age groups, and to track illness changes. Given these alarming figures, the Saudi government must carefully consider developing health and educational policies that ensure efficient treatment of these children while limiting the effects of these conditions on educational performance; there is also a need to better understand what is driving this epidemic in Saudi children and prioritise prioritize the search for effective primary prevention strategies.
Abdul Rahman 2017[30]	Cross-sectional study	Egypt, Iran, Lebanon, Saudi Arabia, and the United Arab Emirates	3 months	Self-report survey	501 (Saudi =100)	3.00%	From 7 years to 88 years (18–88 years of age; mean, 35.0 ± 11.6 years) (4–17 years of age; mean, 10.7 4.0 years).	277 (55.3%)	Adults, children, and adolescents ≥4 years old with a physician diagnosis of AR who were currently experiencing or being treated for AR	The prevalence of AR in Saudi Arabia was 3%, which was lower than in Egypt, Iran, Lebanon, and the United Arab of Emirates.
Sabry 2011[19]	Cross-sectional study	Taif City	11 months	Sabry's Arabic Questionnaire for Allergy Diagnosis-143 (SAQAD-143)	854	52.81%	From 3 years to 65 years	543 (63.58%)	Saudi students, employees, and staff members in at Taif University	The questionnaire proved its capability in aiding the diagnosis of various allergic morbidities. It evidenced a high prevalence of allergic diseases in Taif city. This is an important health issue which that requires the strategic application of primary health care facilities to achieve adequate control.

Harfi 2010[16]	Cross-sectional study	Riyadh, Saudi Arabia	1 month	ISAAC Phase I questionnaire	1100	12.70%	From 6 years to 14 years	285 (25.9%)	School-age children aged 6–14 years in Riyadh, Saudi Arabia	Allergy rhinitis is the most frequent allergic condition in children, followed by bronchial asthma and eczema, showing a significant decline in prevalence rates when compared to previous studies in this region. Food and medication allergies were the least prevalent and non-significant in children. Periodic investigations in different parts of the country would be useful in obtaining a more accurate picture of the prevalence of allergy diseases in Saudi children.
Sobki 2004[15]	Cross-sectional study	From the four main provinces of the kingdom of Saudi Arabia (Central, East, Southern, and West)	NR	(WHO / PDHI) World Health Organization (1992) questionnaire for HI surveys and ISAAC Phase I questionnaire	9540	26.51%	From 4 years to 15 years	5351 (56%)	Children in the Kingdom of Saudi Arabia, the who were association associated with hearing impairment (HI) and bronchial asthma.	The frequency of allergic rhinitis in children is rising in Saudi Arabia, as it is in other parts of the world. Saudi Arabia is divided into several geographic regions, and the prevalence of allergic rhinitis varies by province; living in urban and the use of areas, and using carpets, air conditioning, and domestic pets are new variables in this country. The frequency of allergic rhinitis was shown to be greater in the offspring of consanguineous parents and those with a positive family history of allergy. This might point to inherited genetic risk factors. Within the rhinitis population, there is a significant frequency of HI.

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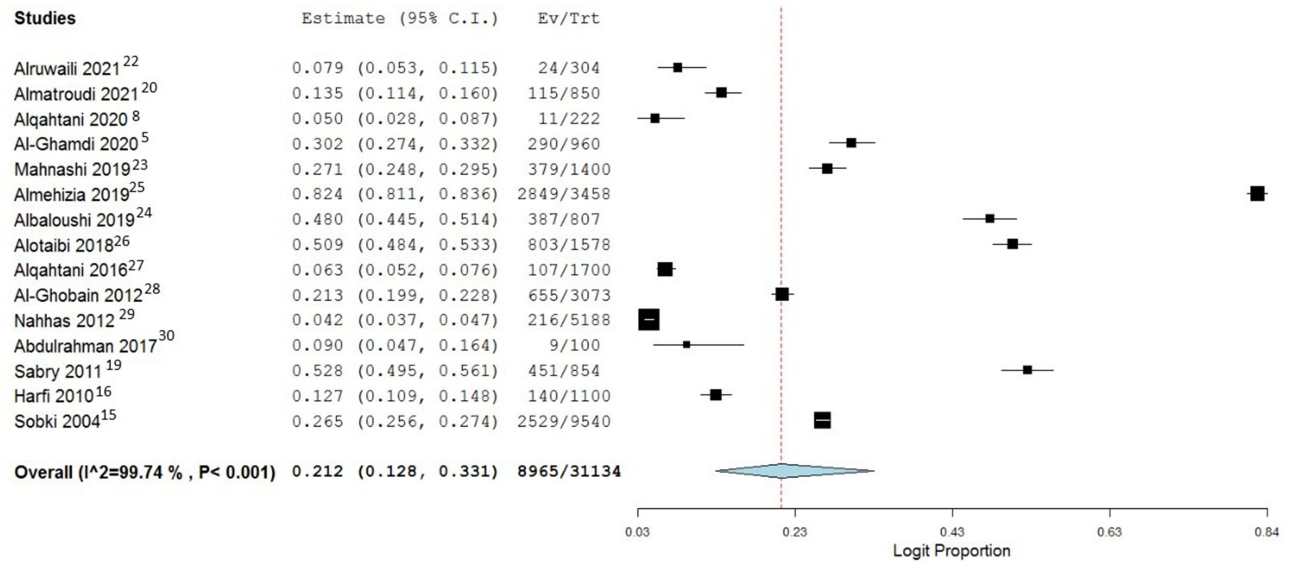

Figure 2 Overall prevalence of AR; shows the forest plot of the random effect estimated prevalence of AR.

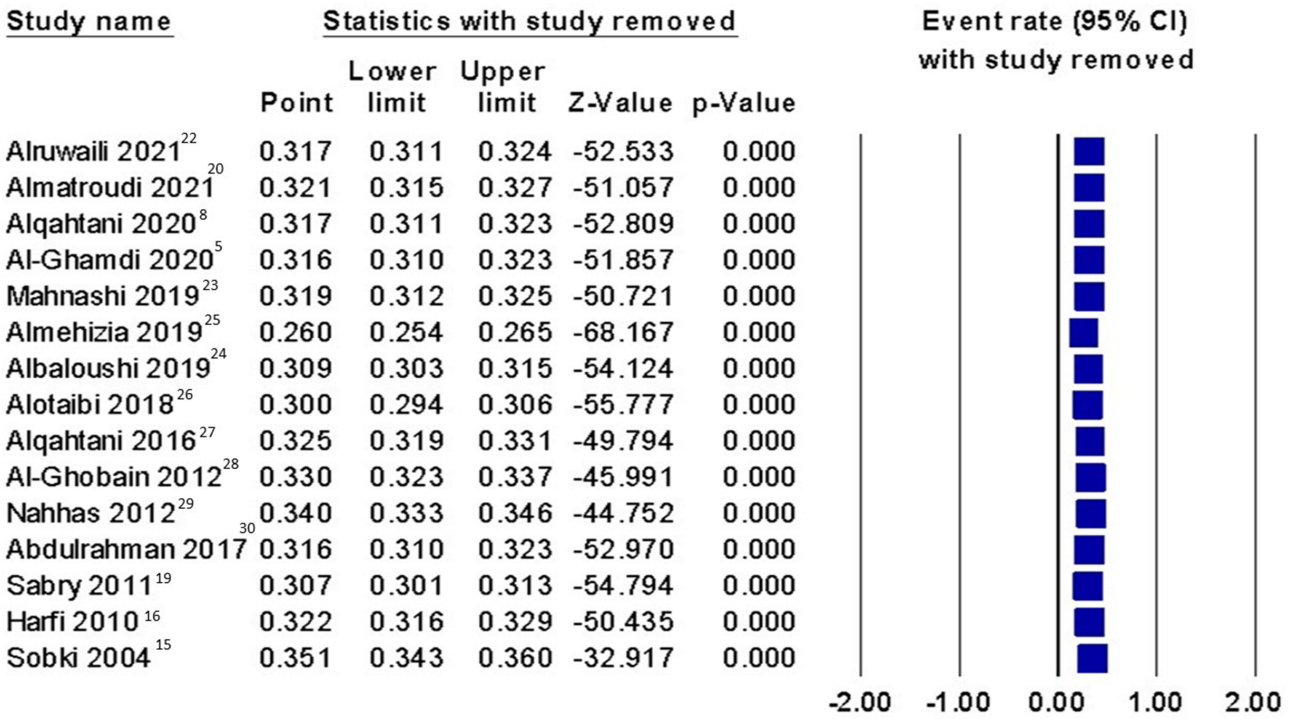

Figure 3 Sensitivity analysis of overall prevalence of AR; shows the sensitivity analysis of overall prevalence of AR.

95% CI (1.50–16.5%), respectively. Based on the quality assessment, there was no substantial difference in terms of the prevalence obtained from good studies and fair studies 20.7%, 95% CI (8.30–43.1%) and 22.3%, 95% CI (13.3–34.8%), respectively. In terms of sample size, studies with a small sample size (≤500) showed a lower prevalence of 7.20%, 95% CI (5.20–9.80%) compared with larger (>2500) sample size 27.3%, 95% CI (7.80–62.5%) (Table 2).

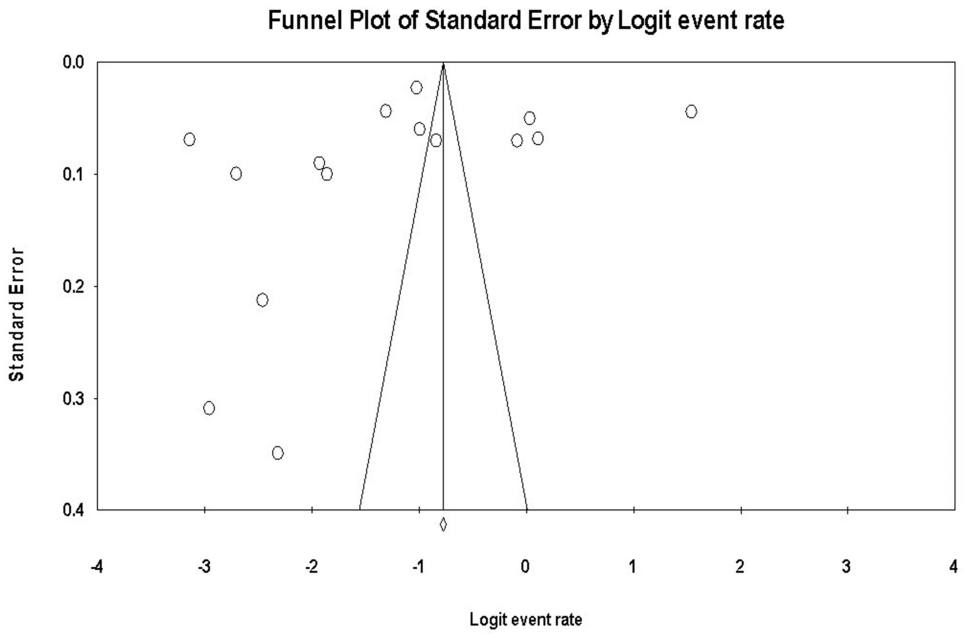

Figure 4 Funnel plot; shows the funnel plot of the overall prevalence of AR.

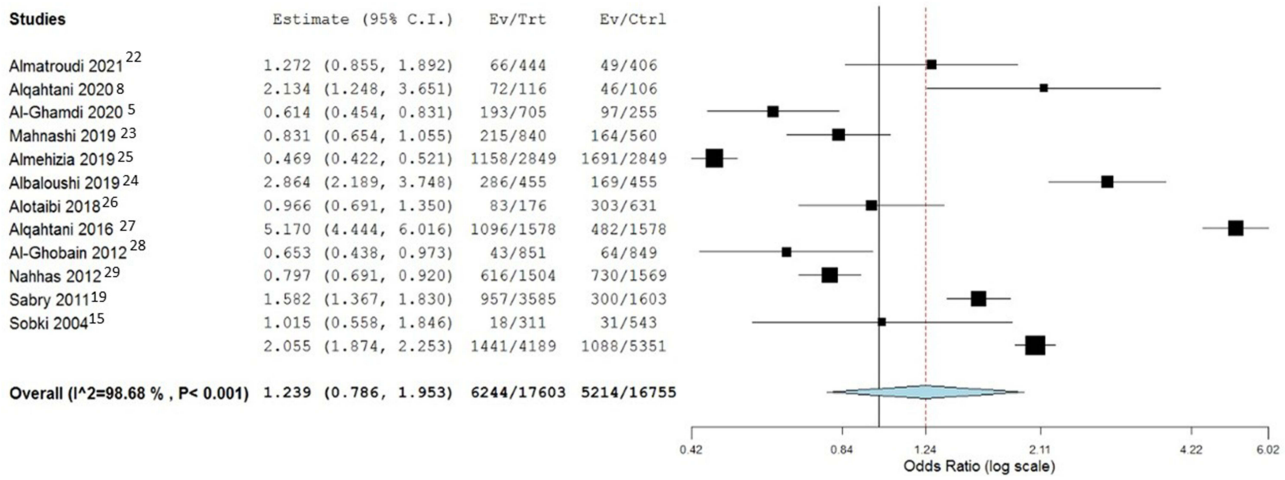

Figure 5 Prevalence of AR in females vs males; shows the forest plot of random-effect estimated odds ratio of the difference between males and females in terms of the prevalence of AR.

Based on the assessment tool, the prevalence of AR retrieved from validated tools such as ISAAC and SAQAD-143 questionnaires was substantially lower than the prevalence retrieved from self-developed tools 16.2%, 95% CI (10.5–24.2%) vs 35.1%, 95% CI (16.5–59.7%), respectively.

Prevalence of Associated Allergies

The pooled analysis of 13 studies showed that the estimated prevalence of asthma associated with AR was 16.8%, 95% CI (11.8–23.4%). The prevalence of associated atopic dermatitis was reported in four studies at 13.6%, 95% CI (4.40–34.8%). In addition, the overall prevalence of associated eczema was 8.50%, 95% CI (4.10–16.8%). Table 3 summarizes the subgroup analysis of associated allergies.

Table 2 Subgroup Analysis Based on the Demographic and Study Characteristics

Prevalence of AR		Prevalence % (95% CI)	I^2; P-value	Number of Studies
Gender	Male	31.7 (24.1–40.4)	99.17%; <0.001	13
	Female	27.1 (18.8–37.3)	99.37%; <0.001	
Age group	Child	12.7 (7.50–20.7)	99.75%; <0.001	7
	Adults	31.1 (11.6–60.9)	99.47%; <0.001	5
	Both	36.5 (24.8–50.1)	95.79%; <0.001	3
Area	Central	29.2 (6.20–72.0)	99.89%; <0.001	4
	Western	18.1 (0.90–84.2)	99.91%; <0.001	2
	Northern	23.0 (2.50–77.6)	99.23%; <0.001	2
	Southern	13.7 (6.20–27.7)	98.98%; <0.001	4
	Eastern	48.0 (44.5–51.4)	-	1
Residency	Rural	13.0 (9.20–17.9)	90.77%; <0.001	3
	Urban	38.4 (7.20–83.4)	99.65%; <0.001	
Smoking	Yes	7.00 (4.70–10.2)	92.20%; <0.001	5
	No	41.4 (18.7–68.5)	99.59%; <0.001	
Family history of allergy in all of the family members	Yes	40 (20.2–63.7)	98.84%; <0.001	3
Allergy relation to a certain period of the year	Summer	17.3 (10.2–27.8)	96.97%; <0.001	4
	Spring	6.00 (1.60–20.6)	98.27%; <0.001	
	Winter	17.6 (9.10–31.1)	98.09%; <0.001	
	Autumn	5.20 (1.50–16.5)	98.01%; <0.001	
QA	Good	20.7 (8.30–43.1)	99.83%; <0.001	9
	Fair	22.3 (13.3–34.8)	99.28%; <0.001	6
Sample size	≤500	7.20 (5.20–9.80)	15.06%; 0.308	3
	501–1500	28.3 (17.5–42.5)	99.10%;<0.001	6
	1501–2500	20.9 (1.80–79.4)	99.83%;<0.001	2
	>2500	27.3 (7.80–62.5)	99.92%;<0.001	4
Assessment tool	Validated	16.2% (10.5–24.2%)	99.44%; p<0.001	10
	Self-developed	35.1% (16.5–59.7%)	99.57%; p<0.001	5

Signs and Symptoms of AR

Table 4 demonstrates that the most common signs and symptoms of AR were headache 33.9%, 95% CI (14.2–61.4%), watery discharge 28.6%, 95% CI (5.70–72.7%), sneezing 24.6%, 95% CI (14.5–38.6%), itchy nose 24.2%, 95% CI (5.40–64.3%), runny nose 22.2%, 95% CI (4.40–63.8%), nasal obstruction or congestion 22.0%, 95% CI (3.20–70.7%),

Table 3 Associated Conditions, Including Asthma, Atopic Dermatitis, and Eczema

Associated Conditions	Prevalence (95% CI)	I^2; P-value	Number of Studies
Prevalence of associated- asthma	16.8 (11.8–23.4)	99.15%; <0.001	13
• Studies less than 500	21.6 (12.5–34.7)	94.12%; <0.001	4
• Studies of more than 500	15.1 (9.90–22.5)	99.36%; <0.001	9
• Children and adolescents	11.5 (6.90–18.4)	99.27%; <0.001	6
• Adults	17.4 (9.50–29.8)	98.11%; <0.001	4
• Both (adults and children)	32.2 (21.6–45.0)	95.59%; <0.001	3
Prevalence of associated- AD	13.6 (4.40–34.8)	99.20%; <0.001	4
• Studies less than 500	6.50 (1.40–24.8)	93.93%; <0.001	2
• Studies of more than 500	25.7 (5.80–66.0)	99.67%; <0.001	2
• Children and adolescents	6.40 (1.50–23.7)	94.98%; <0.001	2
• Adults	13.1 (9.20–18.2)	–	1
• Both (adults and children)	45.4 (42.1–48.8)	–	1
Prevalence of associated- eczema	8.50 (4.10–16.8)	99.32%; <0.001	6
• Studies less than 500	10.3 (7.80–13.5)	–	1
• Studies of more than 500	8.20 (3.60–17.6)	99.46%; <0.001	5
• Children and adolescents	6.40 (2.10–18.1)	99.61%; <0.001	3
• Adults	10.3 (7.80–13.5)	–	1
• Both (adults and children)	11.5 (2.10–44.1)	99.06%; <0.001	2

Table 4 Signs and Symptoms of AR

Signs and Symptoms of AR	Prevalence (95% CI)	I^2; P-value	Number of Studies
Sneezing	24.6 (14.5–38.6)	99.18%; <0.001	7
Runny nose	22.2 (4.40–63.8)	99.36%; <0.001	4
Nasal obstruction or congestion	22.0 (3.20–70.7)	99.54%; <0.001	4
Itchy nose	24.2 (5.40–64.3)	98.55%; <0.001	3
Loss of smell	21.9 (6.80–52.0)	94.53%; <0.001	2
Headache	33.9 (14.2–61.4)	94.97%; <0.001	2
Itchy, reddnes redness or watery eyes	8.60 (5.50–13.1)	71.89%; 0.029	3
Watery discharge	28.6 (5.70–72.7)	97.39%; <0.001	2
Cough	13.8 (6.10–28.5)	96.32%; <0.001	3
Wheeze	17.2 (9.20–29.8)	95.75%; <0.001	3

loss of smell 21.9%, 95% CI (6.80–52.0%), wheeze 17.2%, 95% CI (9.20–29.8%), cough 13.8%, 95% CI (6.10–28.5%), and itchy, redness or watery eyes 8.60%, 95% CI (5.50–13.1%).

Triggers of AR

Our analysis showed that the most prevalent triggers of AR were perfume 36.8%, 95% (14.8–66.1%), dust 27.3%, 95% CI (11.7–51.5%), air conditioning 23.4%, 95% CI (10.0–45.7%), weather or temperature changes 17.8%, 95% CI (6.80–39.3%), air pollution 14.5%, 95% CI (9.10–22.4%), drugs or chemicals 13.8%, 95% CI (7.30–24.4%), tobacco 10.8%, 95% CI (1.60–48.0%), atopy 10.3%, 95% CI (0.30–79.2), insects 10.2%, 95% CI (4.40–22.2%), grass or plant 9.20%, 95% CI (0.30–74.7%), animals like dogs and cats 8.50%, 95% CI (3.40–19.9%), respiratory infections 6.80%, 95% CI (3.40–13.2%), pollen 4.80%, 95% CI (0.50–34.1%) (Table 5).

Table 5 Allergy Triggers

Allergy Triggers	Prevalence % (95% CI)	I^2; P-value	Number of Studies
Air pollution	14.5 (9.10–22.4)	95.51%; <0.001	4
Specific food	4.70 (2.40–9.00)	94.23%; <0.001	6
Dust	27.3 (11.7–51.5)	99.40%; <0.001	7
Animals like dogs and cats	8.50 (3.40–19.9)	99.29%; <0.001	9
Insects	10.2 (4.40–22.2)	94.71%; <0.001	3
Weather or temperature changes	17.8 (6.80–39.3)	93.18%; <0.001	3
Tobacco	10.8 (1.60–48.0)	98.85%; <0.001	3
Respiratory infections	6.80 (3.40–13.2)	58.34%; 0.121	2
Atopy	10.3 (0.30–79.2)	99.35%; <0.001	2
Perfume	36.8 (14.8–66.1)	98.84%; <0.001	3
Air conditioning	23.4 (10.0–45.7)	91.75%; <0.001	2
Grass or plant	9.20 (0.30–74.7)	99.55%; <0.001	2
Pollen	4.80 (0.50–34.1)	98.46%; <0.001	2
Drugs or chemicals	13.8 (7.30–24.4)	89.51%; <0.001	3

Table 6 Effect of AR on Life

Effect of AR on Life	Prevalence % (95% CI)	I^2; P-value	Number of Studies
Stuffy nose (overall)	7.00 (5.90–8.40)	0.00%; 0.694	2
Stuffy noses affect daily activities	7.70 (6.50–9.10)	0.00%; 0.745	2
Difficulty The difficulty of breath due to a stuffy nose	8.80 (4.30–17.1)	89.18%; 0.002	2
Stuffy A stuffy nose caused causes sleep problems	5.80 (3.70–9.10)	73.62%; 0.052	2
Nasal obstructions led to the emergency department	7.90 (1.20–37.8)	97.02%; <0.001	2
Hospital admission due to AR	1.50 (0.10–16.90)	85.75%; 0.008	2
Allergic rhinitis caused causes school absenteeism	6.50 (5.40–7.80)	0.00%; 0.837	2
Allergic rhinitis affects the daily activities (overall)	10.6 (3.10–30.6)	96.42%; <0.001	2

Impact of AR on Daily Activities

The overall prevalence of "AR affects the daily activities" was 10.6%, 95% CI (3.10–30.6%), stuffy nose affects daily activities 7.70%, 95% CI (6.50–9.10%), stuffy nose caused sleep problems 5.80%, 95% CI (3.70–9.10%), difficulty of breath due to stuffy nose 8.80%, 95% CI (4.30–17.1%), nasal obstructions led emergency department 7.90%, 95% CI (1.20–37.8%), AR caused school absenteeism 6.50%, 95% CI (5.40–7.80%), and hospital admission due to AR 1.50%, 95% CI (0.10–16.90%) (Table 6).

Discussion

To the best of our knowledge, this is the first and most comprehensive meta-analysis that evaluates the prevalence of AR in the Saudi population. In Saudi Arabia, there are a variety of climatic and topographical characteristics, making it a

unique country. Our findings showed that the overall prevalence of AR was 21.2%, 95% CI (12.8–33.1%). Adults were associated with a higher prevalence of AR compared to children and adolescents (31.1% vs 12.7%), respectively. In children and adolescents, the lowest reported prevalence was 4.20% and the highest prevalence was 26.51%. In adults, the lowest reported prevalence was 3% and the highest prevalence was 82.40%. AR prevalence ranged from 0.8 to 14.9% in 6–7-year-olds and from 1.4 to 39.7% in 13–14-year-olds in global studies.[31] Asia has a significant population affected by this condition, ranging from 27% in South Korea to 32% in the UAE.[32,33] In a survey of secondary school students, the overall prevalence of AR was 19.3%, of which 52.6% were female and 47.4% were male.[34] Another study reported that seasonal AR was 47.8% and permanent AR was 32.7% with an overall prevalence of 40.8%.[35] The prevalence of AR in children (aged 6–7) in Iranian research varied from 14% to 31.9%.[36,37] These estimated prevalence rates were substantially higher than those reported in Spain and Croatia from the same age group.[38–40] AR was estimated to affect 10–30% of the global population, which is lower than estimates from previous population-based studies in the Netherlands, Finland, Australia, and the United States.[41–44] Surabaya's rates were determined to be higher than in Kota Bahru (Malaysia) or Taoyuan (Taiwan), but equivalent to big cities such as Bangkok (Thailand) or Metro Manila (Republic of The Philippines).[45–48] Regarding adults, around 10% to 30% of individuals in Europe and the United States are affected by AR.[49,50] Approximately 27% of South Koreans and 53% of Malaysians are affected by AR, making Asia one of the most affected regions in the world.[32,51]

Both genders had a comparable prevalence of AR; however, it was slightly higher in males. It was reported that males during childhood are more likely to experience persistent moderate to severe forms of AR as they are more vulnerable to being affected by pollen as a trigger of AR compared to females.[25,52] In addition, Alqahtani J. mentioned that Male and female students were found to have similar levels of diagnosed AR; however, males were significantly associated with atopy and polysensitization.[8] A meta-analysis reported that the prevalence of AR showed a clear male predominance in childhood, while after puberty, it seems that the prevalence switch to be more predominant in females.[53] It was suggested that sex hormones play a role in the homeostasis of immunity; higher levels of sex hormones such as estrogen and progesterone enhance type 2 and suppress type 1 responses in females, whereas testosterone suppresses type 2 responses in males.[54,55] Furthermore, some studies reported that estrogens can enhance antibody synthesis and humoral immunity, while androgens seem to suppress inflammation and immunity.[56,57] In a rat model, estradiol was shown to increase mast cell activation and allergy sensitization; this effect was likely degranulator-selective or allergen-specific. However, progesterone has the opposite effect, increasing IgE production while decreasing histamine release.[58,59]

Based on the geographical regions, the Central region was associated with higher prevalence, followed by the Northern region, the Western region, and the Southern region. In Arar city, the reported prevalence of AR was 7.80% in female students ranging from 15 to 18 years.[22] In the Al-Qassim region, the prevalence of AR in adults was 13.5%.[20] Other cities reported higher prevalence such as Jazan (27.10%),[23] Aseer (30.20%),[5] Al-Ahssa (48%),[24] Taif (52.81%),[19] and Hail (74%).[29] On the other hand, other cities had a lower prevalence of AR such as Madinah (4.20%),[29] and Najran (6.30%).[27]

Moreover, the prevalence of AR in urban areas was considerably higher than in rural areas. A growing body of evidence demonstrates that urbanization is frequently associated with an increase in the incidence of respiratory allergy diseases, such as hay fever (AR) and asthma in children and adults.[60–63] An epidemiological study in Mongolia found that the prevalence of allergic sensitization rose steadily from 13.6% in villages to 25.3% in rural towns to 31.0% in cities, indicating that the degree of socioeconomic development and urbanization may have a direct impact on the prevalence rate of allergic sensitization.[64] An Iranian study showed that the prevalence of AR in urban areas was 21.7% compared to 18.1% in the rural area.[37] An investigation showed that air pollution, smoking, and urban living are considered independent predictors of the relatively high prevalence of AR in Saudi Arabia.[25]

Our findings showed that the prevalence of AR was higher in the summer and winter than spring and autumn. Saudi Arabia is known for its frequent and periodic sandstorms in all seasons. Sandstorms transport many types of micro-organisms and dust particles that can trigger or exacerbate respiratory diseases such as AR and asthma.[65] Meo et al, showed that the four-season sandstorm in Saudi Arabia was associated with increased incidence of wheeze, runny nose, cough, and acute asthmatic attack.[65]

The prevalence of AR in patients who presents with a family history of allergy in all of the family members was 40%, 95% CI (20.2–63.7%). The family history was reported only in three studies.[21,22,25] Furthermore, Alruwaili et al showed that patients who had a sibling with asthma were associated with a higher prevalence of AR (4.3%) compared to 3% who had a mother with allergic rhinitis, 2.3% had a sibling with eczema, 1.6% had father and sibling with AR, and 1% in mother with asthma.[22] Alanazy et al found that 65.7% of the included patients had a family history of AR.[21] Another study by Almehizia et al showed that 64.1% of the patients had a family history of AR.[21] Alqahtani J. admitted that his study has some limitations, including the absence of data regarding social and environmental risk factors, family history of atopic disorders, and the presence of pets or smokers in the family.[8]

Our findings showed that the prevalence of AR retrieved from validated questionnaires was substantially lower than the prevalence of non-validated tools. This finding suggests that the self-developing tools may overestimate the prevalence of AR. Therefore, we recommend employing the validated and commonly used questionnaires, including ISAAC, to accurately estimate the prevalence of AR.

The estimated prevalence of asthma, atopic dermatitis, and eczema associated with AR was 16.8%, 95% CI (11.8–23.4%), 13.6%, 95% CI (4.40–34.8%), and 8.50%, 95% CI (4.10–16.8%), respectively. Several scientific articles supported the link between AR and asthma by showing the similarity of upper and lower respiratory tract anatomy, as well as pathophysiological mechanisms in these two respiratory tracts. Similar inflammatory mediators, immunocompetent cells, and triggers are involved in the inflammation that occurs in both AR and asthma.[66] Patients with allergic rhinitis are three times more likely to develop asthma than those without the condition. Asthma symptoms seem to improve at the same time as the rhinitis symptoms do. Patients with more severe and chronic rhinitis have a greater chance of acquiring asthma.[67] A recent meta-analysis showed a significant association between AR and atopic dermatitis (OR 3.25, 95% CI 2.26–4.66).[68] A large observational study demonstrated that eczema is the second most common condition to be associated with AR after asthma.[69]

Regarding the interference of AR with daily activity and quality of life, a recent meta-analysis showed that patients with AR were associated with a morning headache, daytime sleepiness, difficulty waking up, snoring, obstructive sleep apnea, sleep-disordered breathing, restless sleep, nocturnal enuresis, and insomnia.[70] Nasal congestion, itchy nose, runny nose, and sneezing are all characteristics of AR. The most common and most unpleasant symptom of both adults and children is nasal congestion.[71] Nasal allergies have a significant effect on how a patient feels about their overall health. When compared with other conditions, a Spanish study showed that the negative impact of AR on daily activities was higher than type 2 diabetes mellitus (T2DM) and hypertension.[72] According to a review of relevant literature, there is a strong link between nasal allergies and anxiety/depression.[73] Parent-educator-physician teamwork is essential to ensure good quality of life and maximal school performance in this population.[74]

We acknowledge that our study has some limitations, including the severe, unresolved heterogeneity, which could be attributed to the significant variation between the included studies in terms of assessment tools, population age, geographical area, and season and year of conduction. However, we conducted a sensitivity analysis and subgroup analysis to resolve it, with no significant change. Moreover, the prevalence of AR in the included studies relied mainly on the assessment tools (questionnaires), without confirming the diagnosis with allergic sensitization (IgE test). Another limitation, was the use of self-developing questionnaires and interviews rather than the validated and commonly used questionnaires such as ISAAC, which may overestimate the prevalence of AR.

In conclusion, the overall prevalence of AR in Saudi Arabia is 21.2%. The prevalence of AR was comparable in both males and females. Adults were associated with a higher prevalence of AR compared to children and adolescents. The central region was associated with a higher prevalence of AR compared with other regions. Urban areas had a considerably higher prevalence of AR than rural areas. Asthma, atopic dermatitis, and eczema co-occurrence with AR are common. AR has a negative impact on the quality of life of the patients in the form of interference with daily activities, sleep problems, difficulty of breath, and school absenteeism. Further studies are required to investigate predictors of increased prevalence of AR in Saudi Arabia and the role of mass screening programs on this prevalence. Moreover, studies that investigate the prevalence of AR based on confirmed laboratory tests are required to highlight the accurate prevalence of AR.

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