Review

Prevalence of asthma among children in India: A systematic review and meta-analysis

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ABSTRACT

There is a lack of national-level estimates on the magnitude of asthma among children in India. Hence, we undertook a systematic review and meta-analysis to estimate the prevalence of asthma among children in India. We searched PubMed, Embase, Cochrane Library, and Google Scholar, and included cross-sectional studies reporting data on the prevalence of asthma among children in India. A random-effects model was used to estimate the pooled prevalence of asthma. In the 33 selected studies (pooled sample of 167,626 children), the estimated prevalence of asthma was 7.9% (95% confidence interval: 6.3–9.6%), $I^2 = 99.1\%$ ($P < 0.001$). The prevalence was higher among boys and in urban areas. Appropriate training and resources should be made available at the primary healthcare level for early detection and management of asthma in children. A nationwide population-based survey is indicated to provide reliable estimates of the burden of asthma.

KEY WORDS: Asthma, children, community, India, prevalence, rural, school, urban

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INTRODUCTION

Globally, about 30–35% of children suffer from allergic disorders, and the prevalence of these illnesses has been rising in recent years. Atopic dermatitis, allergic rhinitis, asthma, and food allergies are some of the childhood allergic disorders, of which asthma is the most common chronic condition among children and adults.[1] Asthma leads to the narrowing of the small airways in the lungs due to inflammation, producing wheeze, cough, difficulty in breathing, and chest tightness. It is often under-diagnosed and under-treated, predominantly in low- and middle-income countries, and impacts the quality of life.[2]

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Asthma has a substantial financial impact on both patients and the healthcare system. In addition to the economic expenses, the illness has social implications such as death.[3] Asthma can severely limit the ability to engage in normal daily activities, including sports and outdoor activities, poor sleep, fatigue, and permanent decline in lung function.[4] It accounts for more than 10 million missed school days each year and is the third principal cause of child hospitalization.[5]

In research, defining "asthma" has proven to be a contentious issue. Some epidemiological definitions are

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more sensitive than others, resulting in misclassification. For example, survey definitions based on wheezy breathing alone indicate a higher asthma prevalence than clinical definitions.[6]

Studies conducted to estimate the prevalence of asthma among children in India have reported a varied prevalence (2–18.2%).[7,8] This wide variation in the prevalence could be due to the tool used to estimate the prevalence of asthma, participants' characteristics, and the study setting. The quality of individual studies also varies significantly. Previous studies in India have assessed asthma status among children qualitatively,[9] and these estimates were based on varied diagnostic criteria and definitions of asthma.

In view of the above, we conducted a systematic review and meta-analysis to estimate the pooled prevalence of asthma among children in India.

MATERIALS AND METHODS

Search strategy

A comprehensive literature search was made to identify relevant studies published between the inception of the following databases to 31 August 2021: Medline via PubMed, Embase, Cochrane library, and Google Scholar with no restriction on language using Medical Subject Headings and keywords. The keywords used to build the search strategy were: "prevalence," "epidemiology," "asthma," "children," "school going," "community," and "India." We used the Preferred Reporting Items for Systematic reviews and Meta-Analyses, and Meta-analysis of Observational Studies in Epidemiology statements to guide this study.[10,11] We also reviewed the cross-references of published primary studies.

Inclusion and exclusion criteria

The eligible studies were selected by performing an initial screening of identified titles and abstracts, followed by a full-text review. The following criteria were used for eligibility of studies: (1) school-based or population/community-based studies conducted in India, (2) conducted among children, (3) reported the prevalence of asthma, (4) estimation of the prevalence of asthma should have been based on objective method, and (5) data should be sufficient to obtain the prevalence of asthma. We excluded abstracts, conference proceedings, letters, review articles, editorials, case reports, and studies not conducted on humans. We excluded four studies that had reported the prevalence of only wheeze, because wheeze alone could be due to many causes, including infections. This could lead to misclassification.

Study selection, data extraction, and quality assessment

Two independent reviewers (RAD and SKG) screened all the titles and abstracts of retrieved records from the

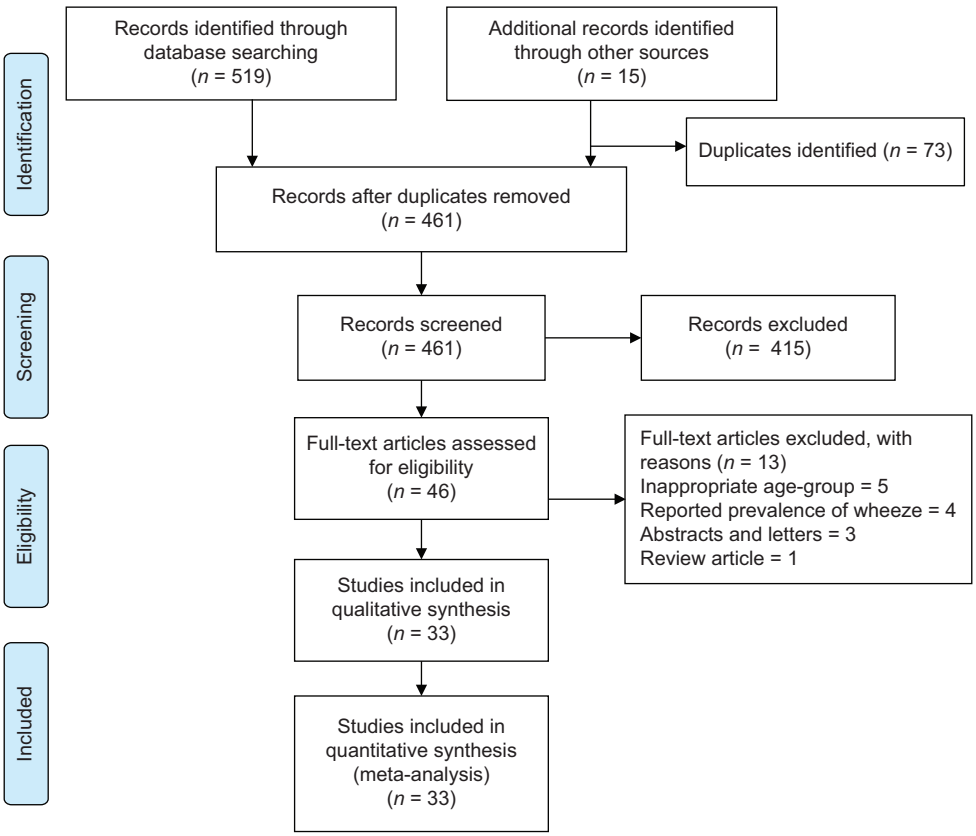

Figure 1: Flow of selection of studies for meta-analysis

databases. Only those abstracts that fulfilled the selection criteria were chosen for the full-text review. Disagreements regarding the selection of studies were discussed and resolved. After verifying the most recent and complete version, duplicates were excluded. Reference lists of the retrieved studies were searched (additional sources). The retrieved full-text studies were judged further to confirm whether they satisfied the inclusion criteria. There was complete agreement between the two reviewers. We devised a data collection form in Microsoft Excel 2013 to extract and enter the relevant data fields from the selected full-text studies. The following data were extracted from each study: author information, year of publication, place of study, study setting, age group, sample size, the tool used for assessment of asthma, and the reported prevalence of asthma. Quality assessment of the selected studies was done based on the Critical Appraisal Skills Programme checklist.[12]

Data synthesis and statistical analysis

We provided summary estimates of the prevalence of asthma among children and used a 95% confidence interval (CI) to gauge the precision of the summary estimate. The standard error of the prevalence was calculated from the prevalence and the sample size from each included study. Forest plots were created to display the prevalence with 95% CI. The meta-analysis was performed by package metan[13] in STATA 14.0[14] (Stata Corp LP, College Station, TX, USA) using a random-effects model, weighted by the inverse of the variance. I^2 statistic (percentage of residual variation attributed to heterogeneity) was performed to evaluate heterogeneity. Publication bias was assessed by visual inspection of the funnel plot, and Egger's test evaluated the small-study effect. To investigate the observed heterogeneity, subgroup analysis was done based on gender, study setting, and the tool used to identify asthma. Sensitivity analysis was conducted to assess the changes in pooled estimates after removing one large multicentric study. A test of interaction was also done to determine if any significant difference was present in the prevalence of asthma between subgroups.

RESULTS

Overall, 534 studies were retrieved from electronic databases. After removing duplicates (73 studies), 461 studies were screened based on titles and abstracts using

Table 1: Characteristics of studies included in the meta-analysis

Author	Year	Study area and state	Study setting	School/ community	Age-group	Tool used
Chhabra *et al*.[17]	1998	New Delhi	Urban	School	4,17	Self-developed
Chhabra *et al*.[18]	1999	New Delhi	Urban	School	5,16	Modified ATS* and BMRC†
Gupta *et al*.[19]	2001	Chandigarh, Haryana	Urban	School	9,20	Modified IUATLD‡
Chakravarthy *et al*.[20]	2002	Chengalpattu and Chennai, Tamil Nadu	Mixed**	Community	0,12	Modified ISAAC§
Awasthi *et al*.[21]	2004	Lucknow, Uttar Pradesh	Urban	School	6,7 & 13,14	ISAAC
Pakhale *et al*.[22]	2008	Washim, Maharashtra	Rural	School	13,14	ISAAC
Behl *et al*.[23]	2010	Shimla, Himachal Pradesh	Urban	School	6,13	ISAAC
Jain *et al*.[24]	2010	Manipal, Karnataka	Rural	Community	6,15	Modified ISAAC
Dhabadi *et al*.[25]	2012	Madikeri, Karnataka	Rural	School	13,17	Self-developed
Kumar *et al*.[26]	2012	Puducherry, Puducherry	Rural	School	12,15	Modified ISAAC
Mathew *et al*.[27]	2012	Coimbatore, Tamil Nadu	Urban	School	5,10 & 11,15	ISAAC
Cheraghi *et al*.[28]	2012	Pune, Maharashtra	Urban	School	6,7 & 13,14	ISAAC
Sharma *et al*.[29]	2013	Kanpur, Uttar Pradesh	Rural	School	5,15	Modified ISAAC
Kumar *et al*.[30]	2014	Puducherry, Puducherry	Urban	School	12,16	Modified ISAAC
Amir *et al*.[31]	2015	Agra, Uttar Pradesh	Urban	School	6,12	ISAAC
Arora *et al*.[32]	2015	Ludhiana, Punjab	Urban	School	5,15	Modified IAP
Arun *et al*.[33]	2015	Davangere, Karnataka	Mixed	School	12,15	ISAAC
Kumar *et al*.[34]	2015	New Delhi, New Delhi	Mixed	Community	7,15	Modified ATS, BMRC&ISAAC
Qureshi *et al*.[35]	2016	Srinagar, Jammu & Kashmir	Mixed	Community	10,16	Modified ISAAC & ECRHS‖
Rambabu *et al*.[36]	2016	Kakinada, Andhra Pradesh	Mixed	Community	9,14	ISAAC
Singh *et al*.[15]	2016	Multicentric	Mixed	School	6,7 & 13,14	ISAAC
Kamath *et al*.[37]	2017	Mangalore, Karnataka	Urban	School	6,15	ISAAC
Kumar *et al*.[38]	2017	Meerut, Uttar Pradesh	Mixed	School	6,13	Modified ISAAC
Lalu *et al*.[39]	2017	Ernakulam, Kerala	Mixed	School	16,19	Modified IUATLD
Naik & Ravikumar[40]	2017	Tumakuru, Karnataka	Rural	School	6,12	ISAAC
Vyankatesh *et al*.[41]	2017	Bhopal, Madhya Pradesh	Urban	School	12,17	Modified ISAAC
Bhalla *et al*.[42]	2018	Rohtak, Haryana	Urban	School	11,16	ISAAC
Gupta *et al*.[8]	2018	Jaipur, Rajasthan	Urban	School	5,15	Modified ISAAC
Kumari and Jagzape[43]	2019	Raipur, Chhattisgarh	Urban	Community	6,14	ISAAC
Sen *et al*.[44]	2019	Namakkal, Tamil Nadu	Urban	School	12,15	ISAAC
Kaushal *et al*.[45]	2020	Jodhpur, Rajasthan	Mixed	School	6,7 & 13,14	ISAAC
Patra *et al*.[46]	2021	Patna, Bihar	Urban	School	6,16	Modified ISAAC
Rashmi *et al*.[7]	2021	Vijayapura, Karnataka	Rural	Community	5,15	ISAAC

*ATS=American Thoracic Society.†BMRC=British Medical Research Council.‡IUATLD=International Union Against Tuberculosis and Lung Diseases.§ISAAC=International study of Asthma and Allergy in Childhood.‖ECRHS=European Community Respiratory Health Survey.**Mixed – includes urban and rural

the selection criteria. A total of 46 eligible abstracts were selected, and their full texts were screened. Finally, 33 studies satisfied the inclusion criteria and were included in the meta-analysis [Figure 1].

Characteristics of studies included in the meta-analysis

The 33 studies included in this review yielded a combined total of 167,626 children (45.3% girls). Of the 33 studies, 26 were school-based and 7 were community-based. All selected studies were cross-sectional, of which one was a multicentric study.[15] The age group included in these studies ranged from 4 to 20 years, with a mean of 12.6 years. In urban areas 18 studies were conducted; seven in rural areas and eight were in mixed (urban and rural) population. To identify asthma, 16 studies used the International Study of Asthma and Allergy in Children (ISAAC) tool[16] and 9 studies used the modified ISAAC tool, while 8 studies used other tools. Most studies recruited the participants based on simple random sampling.

Five studies reported the prevalence of asthma in two age groups, of which two studies gave age-group-wise prevalence as well as the summary estimate. We calculated the summary estimate using the reported prevalence and sample size for the other three studies. Of these five studies, four reported sex distribution for individual age groups. We calculated the average proportion of girls using their age-group-wise sample.

The outcome measure was the prevalence of asthma in children. Of the total 33 studies, the reported prevalence was as follows: a) 11 studies reported prevalence of asthma, which was taken as such, b) 4 studies reported prevalence of only "ever asthma," which was taken as the prevalence of asthma, c) 13 studies reported prevalence of only "current asthma," which was taken as the prevalence of asthma, d) 3 studies reported prevalence of both "ever asthma" and "current asthma" in which "current asthma" was included in "ever asthma," so prevalence of "ever asthma" was taken as the prevalence of asthma, and e) 2 studies reported prevalence of both "ever asthma" and "current asthma" in which "current asthma" was not included in "ever asthma," but have also reported prevalence of "cumulative asthma," which was taken as the prevalence of asthma.[17,18] Table 1 shows the characteristics of studies included in the meta-analysis.

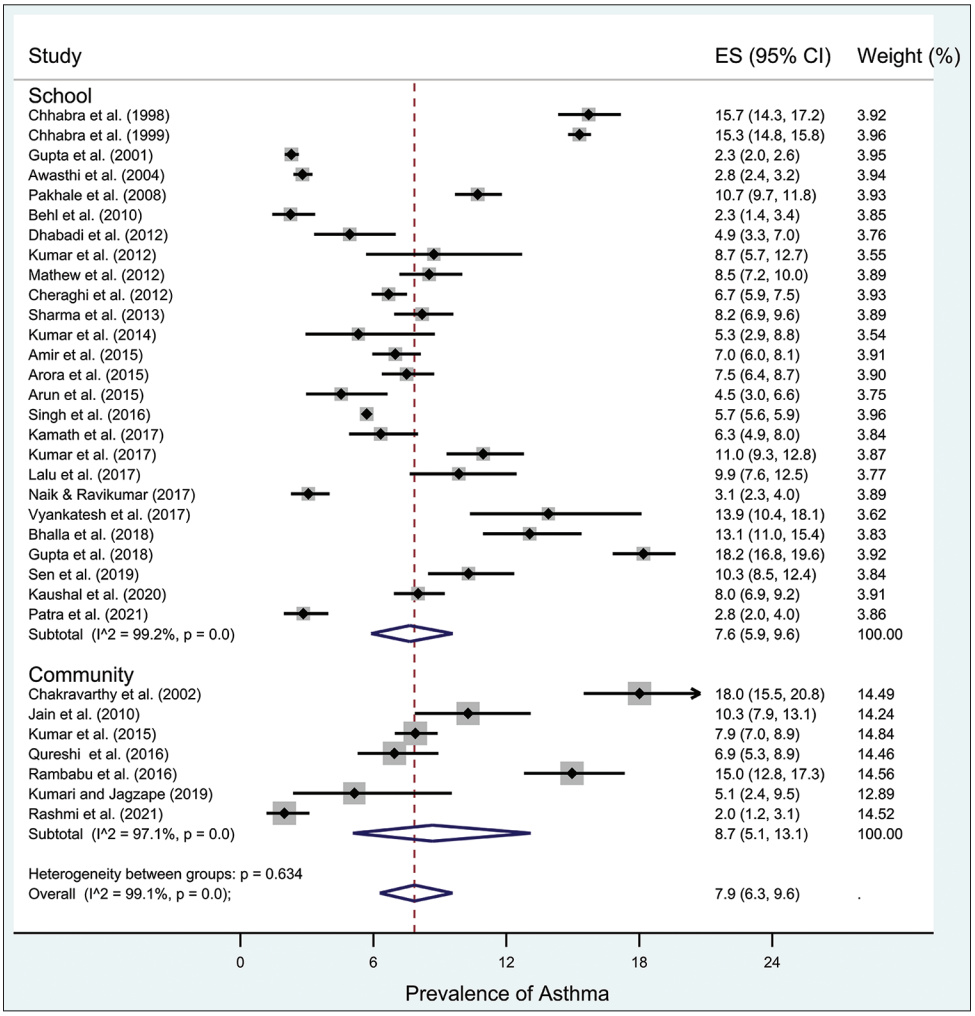

Figure 2: Forest plot of the meta-analysis for the prevalence of asthma

For subgroup analysis, forest plots were prepared separately for school-based and community-based studies. For the sake of brevity, and as 26 out of 33 studies were school-based, only their forest plots have been included in the manuscript. However, the results of subgroup analysis of the seven community-based studies have been reported in the text.

Prevalence of asthma among children in India

The prevalence of asthma in 33 included studies ranged from 2% in a study conducted by Rashmi *et al*.[7] in Karnataka, to 18.2% by Gupta *et al*.[8] conducted in Rajasthan [Table 2]. The random-effects pooled estimate for the prevalence of asthma among children was 7.9% (95% CI: 6.3–9.6%) [Figure 2]. The heterogeneity test showed an I^2 value of 99.1% and a *P* value of < 0.001. The prevalence of asthma was 7.6% (95% CI: 5.9–9.6%) in school-based studies and 8.7% (95% CI: 5.1–13.1%) in community-based studies.

Prevalence of asthma based on gender

Among the 33 studies, the gender-wise prevalence of asthma was available in 13 school-based studies and three community-based studies. The prevalence of asthma among boys and girls in school-based studies was 8.0% (95% CI: 4.8–11.9%) and 5.9% (95% CI: 3.2–9.3%), respectively. We did not observe any decrease in heterogeneity in this subgroup. There was no significant difference in the heterogeneity between the studies based on gender, as shown in Figure 3 (*P*-value = 0.394). As only three community-based studies reported gender-wise prevalence, no analysis was undertaken to obtain summary estimates.

Prevalence of asthma based on study setting

Out of the 26 school-based studies, 16 studies were conducted in urban areas, 5 studies in rural areas, and 5 in both urban and rural areas, categorized as "mixed." The prevalence of asthma in the urban, rural, and mixed areas was 7.9% (95% CI: 5.0–11.4%), 6.8% (95% CI: 3.9–10.5%), and 7.6% (95% CI: 5.5–10.1%), respectively. We did not observe any decrease in heterogeneity. There was no significant difference in the heterogeneity between the studies based on the study setting, as shown in Figure 4 (*P*-value = 0.899).

Of the seven community-based studies, two studies were conducted in rural, one in urban, and four in a mixed population. The prevalence of asthma in these regions was 4.4% (95% CI: 3.4–5.5%), 5.1% (95% CI: 2.4–9.5%), and 11.5% (95% CI: 7.0–17.1%), respectively. We did not observe any decrease in heterogeneity. There was a significant difference in the heterogeneity between the studies (*P*-value < 0.001).

Table 2: Prevalence of asthma among children in India

Author	Year	Sample size	Prevalence (boys)	Prevalence (girls)	Prevalence of asthma (total)
Chhabra *et al*.[17]	1998	2609	16.5	14.8	15.7*
Chhabra *et al*.[18]	1999	18,955	16.6	13.7	15.3*
Gupta *et al*.[19]	2001	9090	2.6	1.9	2.3
Chakravarthy *et al*.[20]	2002	855	NA‡	NA	18
Awasthi *et al*.[21]	2004	3000 and 3000 (6000)	NA	NA	2.3 and 3.3 (2.8) †
Pakhale *et al*.[22]	2008	3390	12.6	8.3	10.7
Behl *et al*.[23]	2010	1017	3	1.4	2.3
Jain *et al*.[24]	2010	555	12.1	8.4	10.3
Dhabadi *et al*.[25]	2012	588	NA	NA	4.9
Kumar *et al*.[26]	2012	275	NA	NA	8.7
Mathew *et al*.[27]	2012	820 and 742 (1562)	NA	NA	9.5 and 7.3 (8.5) †
Cheraghi *et al*.[28]	2012	1990 and 1919 (3909)	8.1	4.9	7 and 6.3 (6.7)
Sharma *et al*.[29]	2013	1695	NA	NA	8.2
Kumar *et al*.[30]	2014	263	5.4	5.2	5.3
Amir *et al*.[31]	2015	2175	8	5.9	7
Arora *et al*.[32]	2015	2000	9.2	5.8	7.5
Arun *et al*.[33]	2015	550	5.1	3.8	4.5
Kumar *et al*.[34]	2015	3104			7.9
Qureshi *et al*.[35]	2016	806	8.3	6.6	7.4
Rambabu *et al*.[36]	2016	989	17.7	12.7	15
Singh *et al*.[15]	2016	44,928 and 48,088 (93,016)	NA	NA	5.4 and 6.1 (5.7) †
Kamath *et al*.[37]	2017	1011	NA	NA	6.3
Kumar *et al*.[38]	2017	1287	10.3	12	11
Lalu *et al*.[39]	2017	629			9.9
Naik & Ravikumar[40]	2017	1631	3.4	2.8	3.1
Vyankatesh *et al*.[41]	2017	331	NA	NA	13.9
Bhalla *et al*.[42]	2018	927	19	7.6	13.1
Gupta *et al*.[8]	2018	2925	NA	NA	18.2
Kumari and Jagzape[43]	2019	175	NA	NA	5.1
Sen *et al*.[44]	2019	991	NA	NA	10.3
Kaushal *et al*.[45]	2020	380 and 1865 (2245)	NA	NA	6.6 and 8.3 (8)
Patra *et al*.[46]	2021	1163	3.1	2.6	2.8
Rashmi *et al*.[7]	2021	908	NA	NA	2

*Reported as cumulative prevalence in the article.†Summary estimate was calculated from the prevalence of individual age groups.‡NA=Not available

Prevalence of asthma based on the tool used

Out of the 26 school-based studies, 13 studies used the ISAAC tool to estimate the prevalence of asthma, 7 studies used modified ISAAC, and 6 studies used tool(s) other than ISAAC and were categorized as "others." The prevalence of asthma among these groups was 6.5% (95% CI: 5.2–7.9%), 9.2% (95% CI: 5.1–14.4%), and 8.6% (95% CI: 3.3–16.0%), respectively. We did not observe any decrease in heterogeneity. There was no significant difference in the heterogeneity between the studies based on the tool used, as shown in Figure 5 (*P*-value = 0.422).

Of the seven community-based studies, three studies used the ISAAC tool, two studies used the modified ISAAC tool, and two studies were categorized as others. The prevalence of asthma among these groups was 6.4% (95% CI: 0.4–18.2%), 14.8% (95% CI: 12.9–16.7%), and 7.7% (95% CI: 6.9–8.5%), respectively. There was a significant difference in the heterogeneity between the studies (*P*-value < 0.001).

Quality assessment

Across the nine quality domains evaluated, most of the studies met five or more of the quality criteria [Table 3]. Four studies met all the quality criteria assessed.[21,24,27,39]

Seven studies mentioned the confidence intervals in their main results. Out of 33 studies, 16 studies calculated a minimum sample size *a priori*. Four studies did not clearly explain the method of selection of the participants. Most of the studies achieved a satisfactory response rate.

Publication bias

The funnel plot demonstrated symmetry [Figure 6], and the *P* value for Egger's test was observed to be 0.06, implying no or undetected publication bias.

Sensitivity analysis

Sensitivity analysis was performed by removing one large multicentric study by Singh *et al.*[15] with a sample size of 93,016, which showed no substantial change in the prevalence of asthma [7.9% (95% CI: 6.1–10.0%)].

DISCUSSION

We conducted a systematic review and meta-analysis of data from 33 studies involving 167,626 participants and found a pooled prevalence of asthma of 7.9% (95% CI: 6.3–9.6%) among them. The pooled prevalence estimate

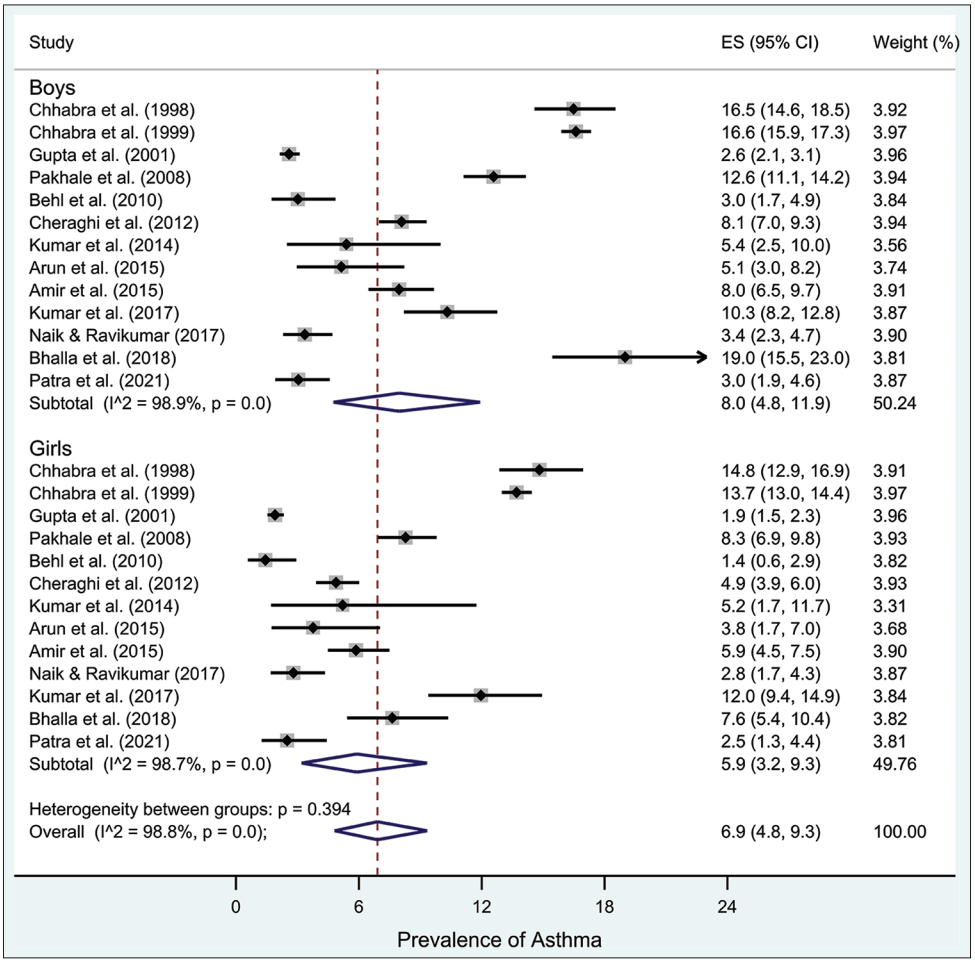

Figure 3: Forest plot of the meta-analysis for the prevalence of asthma by gender (school-based studies)

Table 3: Risk of bias assessment of the studies included in the meta-analysis

Question	Chhabra *et al.*	Chhabra *et al.*	Gupta *et al.*	Chakravarthy *et al.*	Awasthi *et al.*	Pakhale *et al.*	Behl *et al.*	Jain *et al.*
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Could the way the sample was obtained introduce (selection) bias?	No	No	No	No	No	No	No	No
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Was the sample size based on pre-study considerations of statistical power?	No	Yes	No	No	Yes	No	No	Yes
Was a satisfactory response rate achieved?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	No	No	No	Yes	Yes	No	Yes

Question	Dhabadi *et al*	Kumar *et al.*	Mathew *et al.*	Cheraghi *et al.*	Sharma *et al.*	Kumar *et al.*	Amir *et al.*	Arora *et al.*	Arun *et al.*
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Could the way the sample was obtained introduce (selection) bias?	No	No	No	No	Cannot say	No	No	No	Cannot say
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Yes	Cannot say	Yes	Yes	Yes	Cannot say
Was the sample size based on pre-study considerations of statistical power?	No	Yes	Yes	Yes	No	Yes	No	Yes	No
Was a satisfactory response rate achieved?	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	No	Yes	No	No	No	No	Yes	No

Question	Kumar *et al.*	Qureshi *et al.*	Rambabu *et al.*	Singh *et al.*	Kamath *et al.*	Kumar *et al.*	Lalu *et al.*	Naik & Ravikumar	Vyankatesh *et al.*
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Could the way the sample was obtained introduce (selection) bias?	No	No	No	No	Cannot say	No	No	No	No
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Yes	Cannot say	Yes	Yes	Yes	Yes
Was the sample size based on pre-study considerations of statistical power?	No	Yes	No	No	Yes	Yes	Yes	No	No
Was a satisfactory response rate achieved?	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	No	No	Yes	No	No	Yes	No	No

Question	Bhalla *et al.*	Gupta *et al.*	Kumari and Jagzape	Sen *et al.*	Kaushal *et al.*	Patra *et al.*	Rashmi *et al.*
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	No	Yes	No	Yes
Could the way the sample was obtained introduce (selection) bias?	No	No	No	Cannot say	No	No	No
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Cannot say	Yes	Yes	Yes
Was the sample size based on pre-study considerations of statistical power?	Yes	No	Yes	No	Yes	Yes	No
Was a satisfactory response rate achieved?	Yes	Yes	Yes	Yes	Yes	No	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	No	No	No	No	No	No

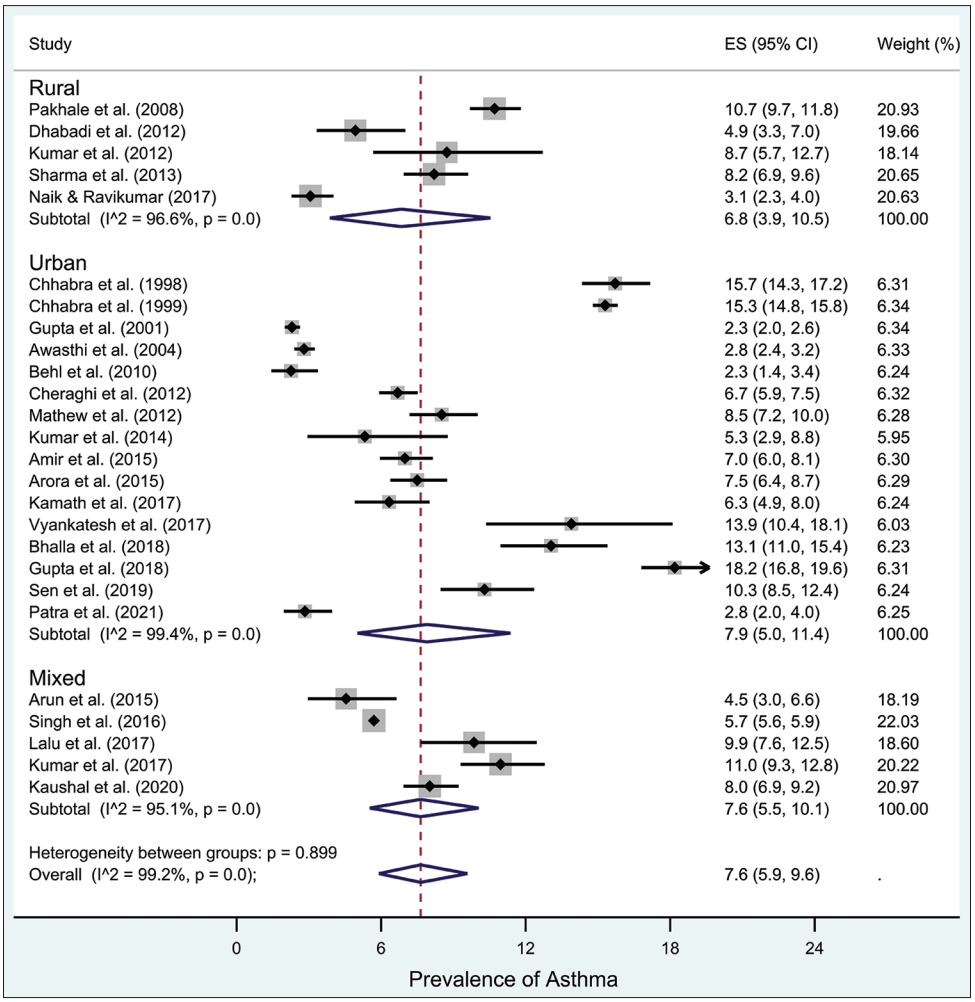

Figure 4: Forest plot of the meta-analysis for the prevalence of asthma by study setting (school-based studies)

was higher in boys when compared to girls (8% vs 5.9%). The studies included in this review had high heterogeneity among them. We conducted subgroup analysis based on gender, study setting, and tool used to estimate the prevalence of asthma, but we could not find the reason for heterogeneity.

Our study findings resonate with a qualitative review done by Pal *et al*.[9] published in 2009 on bronchial asthma among Indian children (mean prevalence was 7.24% ± standard deviation (SD) 5.42%).

A systematic review and meta-analysis conducted in Iran by Varmaghani *et al*.[47] in 2016 estimated that the prevalence of asthma among children under 18 years was 4.87% (95% CI: 4.29–5.46%) which is lower than our study's estimate. Another two meta-analyses from Iran to estimate the prevalence of asthma among children by Ghaffari and Aarabi[48] in 2013 and Hassanzadeh *et al*.[49] in 2012 reported a pooled prevalence of 3.04% (95% CI: 2.5–3.6%) and 4.4% (95% CI: 3.7–5.1%), respectively. These estimates are also lower than our study's pooled estimate.

All the above estimates were exclusively based on studies conducted using the ISAAC tool for estimating the prevalence of asthma among children. The prevalence of asthma in our meta-analysis among studies that have solely used the ISAAC tool was 6.5% (95% CI: 5.2–7.9%), which is a little higher than the studies from Iran. Differences in prevalence estimates might be due to socioeconomic status, climate, air pollution, exposure to respiratory infection, diet, and nutrition.

Asthma is often characterized by wheezing, cough, breathlessness, and chest tightness[41] symptoms which may vary over time, and are common to adults and children. It is essential to obtain the information related to asthma either by doctor-observed symptoms, through previous health records, or by administering an objective, valid questionnaire. Also, one of the significant issues is the wrong assumption that all noisy breathing is wheeze, which leads to the misdiagnosis of asthma. Other factors that could lead to the misdiagnosis of asthma are the inability to identify the reversible airflow obstruction, the relatively low sensitivity of spirometry alone to definitively diagnose asthma (particularly in children), the day-to-day

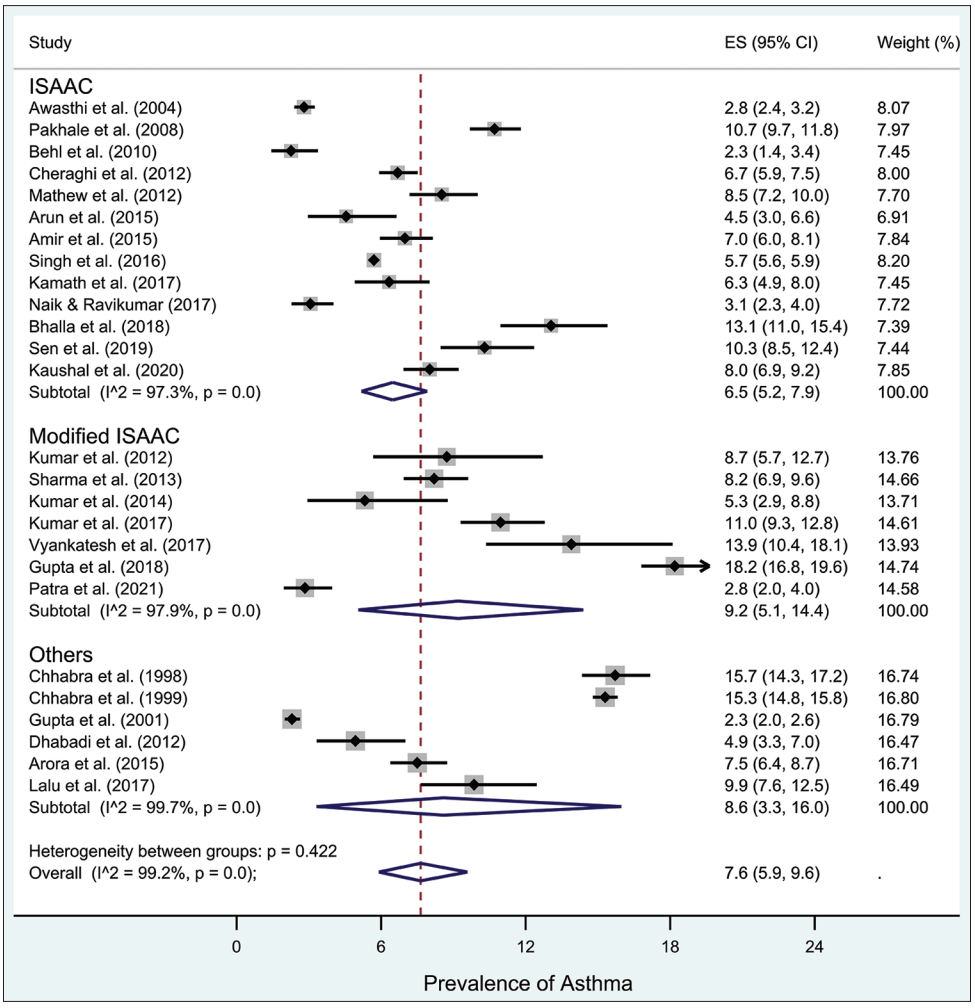

Figure 5: Forest plot of the meta-analysis for the prevalence of asthma by tool used (school-based studies)

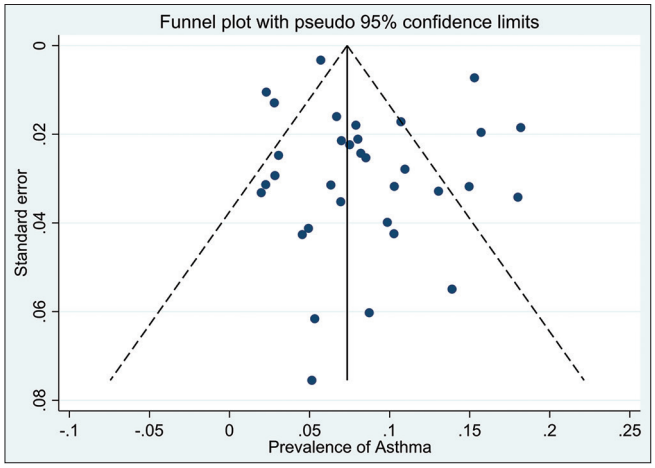

Figure 6: Funnel plot for assessing publication bias

changeability of symptoms, and the plentiful phenotypes of the disease leading to ineffective therapy and a loss of opportunity and time in determining the cause of the patient's respiratory problems.[2] There is a need to add objective testing for the diagnosis of asthma to minimize the potential negative impacts of an incorrect diagnosis.[50] Improvement in spirometry readings following bronchodilator is more sensitive in children and is vital to help confirm a diagnosis of asthma.[51] Epidemiological data is based mainly on questionnaire-reported symptoms, which may not always be accurate, resulting in variations in the prevalence rates of asthma.[52] Although confirming reversible airflow restriction is just as critical in children as in adults when diagnosing asthma, the practical application of spirometry in children is even more difficult. These concerns were highlighted by statistics from the United States, which showed that while 52% of physicians who offered primary care to children used spirometry, only 21% used it according to national recommendations and only 35% of those surveyed were confident in interpreting the test results.[53] Another study reported that 21% of spirometry values were misinterpreted,[54] highlighting the importance of training and quality control before using spirometry on children in primary care.

The use of medications and adherence are major hindrances in the management of asthma, especially at the primary care level. A large percentage of patients are

non-compliant, and the majority of them do not maintain proper inhaler techniques.[55,56] According to current data, poor adherence is still as high as 50–90%, with improper inhaler technique accounting for 70–80%.[55–58] Hence, the primary care physicians should be trained frequently on medication management and should conduct frequent health promotional activities to educate and help people maintain correct techniques for medication use and good adherence. If not a spirometer, at least peak flow meters should be available at the primary health care level to quantify the peak expiratory flow rate as a baseline for future reference and monitoring. Persons with asthma and their families require education to learn more about their condition, treatment options, triggers to avoid, and how to manage symptoms at home. It is also critical to improve community awareness and dispel the myths and stigmas surrounding asthma in particular situations. Smoking cessation, avoidance of exposure to passive smoking, and control of indoor and outdoor air pollution must be implemented at the policy level as these are easily modifiable risk factors for asthma. The importance of physical activity and regular exercises must be informed to the patients.

We have systematically searched various electronic databases to identify school and community-based studies that have estimated the prevalence of asthma among children in India. In total, we identified 33 studies, which allowed us to pool results from 167,626 participants. We used a standard search strategy, risk of bias assessment for individual studies, explored heterogeneity using subgroup analysis, and performed sensitivity analysis. The findings of this systematic review and meta-analysis should be interpreted with the following limitations. Even though we followed a comprehensive search strategy, we did not include the grey literature, which might affect the pooled estimate. The pooled prevalence estimate from this study has to be interpreted cautiously as there is high heterogeneity among the studies.

CONCLUSIONS

Our findings point to a significant prevalence of asthma among children in India. National-level estimates are needed to capture the trend in the burden of asthma among children. Interventions for control of asthma need to start from the primary healthcare level by educating the community, prioritizing essential drugs and equipment, as well as training the medical personnel for accurate diagnosis and management.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Dharmage SC, Perret JL, Custovic A. Epidemiology of asthma in children and adults. Front Pediatr 2019;7:246.
2. MacNeil J, Loves RH, Aaron SD. Addressing the misdiagnosis of asthma in adults: Where does it go wrong? Expert Rev Respir Med 2016;10:1187–98.
3. Nurmagambetov T, Kuwahara R, Garbe P. The Economic Burden of Asthma in the United States, 2008-2013. Ann Am Thorac Soc 2018;15:348–56.
4. Lizzo JM, Cortes S. Pediatric Asthma. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2021. Available from: http://www.ncbi.nlm.nih.gov/books/NBK551631/. [Last accessed on 2021 Nov 01].
5. The Impact of Asthma. Available from: https://www.lung.org/lung-health-diseases/lung-disease-lookup/asthma/learn-about-asthma/impact-of-asthma. [Last accessed on 2021 Oct 30].
6. Jenkins MA, Clarke JR, Carlin JB, Robertson CF, Hopper JL, Dalton MF, *et al*. Validation of questionnaire and bronchial hyperresponsiveness against respiratory physician assessment in the diagnosis of asthma. Int J Epidemiol 1996;25:609–16.
7. Rashmi BM, Patil SS, Sindhu BM, Patil SV. Pediatric asthma: Prevalence and socio-cultural factors affecting asthma management in a rural area of Northern Karnataka. Indian J Community Med 2021;46:24-9.
8. Gupta MK, Patodia J, Chaudhary P, Kakkar M. The rising trend of asthma prevalence in urban school children of Jaipur: A questionnaire based study. Indian J Allergy Asthma Immunol 2018;32:10-4.
9. Pal R, Dahal S, Pal S. Prevalence of bronchial asthma in Indian children. Indian J Community Med 2009;34:310–6.
10. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, *et al*. Meta-analysis of observational studies in epidemiology: A proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA 2000;283:2008–12.
11. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. BMJ 2009;339. Available from: https://www.bmj.com/content/339/bmj.b2535. [Last accessed on 2021 Nov 01].
12. CASP Critical Appraisal Skills Programme Oxford UK. Critical Appraisal Skills Programme. Available from: http://www.casp-uk.net. [Last accessed on 2021 Nov 01].
13. Harris RJ, Deeks JJ, Altman DG, Bradburn MJ, Harbord RM, Sterne JA. Metan: Fixed- and random-effects meta-analysis. Stata J Promot Commun Stat Stata 2008;8:3–28.
14. Stata 14 | Stata. Available from: https://www.stata.com/stata14/. [Last accessed on 2021 Nov 01].
15. Singh S, Sharma BB, Sharma SK, Sabir M, Singh V. Prevalence and severity of asthma among Indian school children aged between 6 and 14 years: Associations with parental smoking and traffic pollution. J Asthma 2016;53:238–44.
16. The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee. Worldwide variations in the prevalence of asthma symptoms: The International Study of Asthma and Allergies in Childhood (ISAAC). Eur Respir J 1998;12:315-35.
17. Chhabra SK, Gupta CK, Chhabra P, Rajpal S. Prevalence of bronchial asthma in schoolchildren in Delhi. J Asthma 1998;35:291–6.
18. Chhabra SK, Gupta CK, Chhabra P, Rajpal S. Risk factors for development of bronchial asthma in children in Delhi. Ann Allergy Asthma Immunol 1999;83:385–90.
19. Gupta D, Aggarwal AN, Kumar R, Jindal SK. Prevalence of bronchial asthma and association with environmental tobacco smoke exposure in adolescent school children in Chandigarh, north India. J Asthma 2001;38:501–7.
20. Chakravarthy S, Singh RB, Swaminathan S, Venkatesan P. Prevalence of asthma in urban and rural children in Tamil Nadu. Natl Med J India 2002;15:260–3.
21. Awasthi S, Kalra E, Roy S, Awasthi S. Prevalence and risk factors of asthma and wheeze in school-going children in Lucknow, North India. Indian Pediatr 2004;41:1205–10.
22. Pakhale S, Wooldrage K, Manfreda J, Anthonisen N. Prevalence of asthma symptoms in 7th- and 8th-grade school children in a rural region in India. J Asthma 2008;45:117–22.
23. Behl RK, Kashyap S, Sarkar M. Prevalence of bronchial asthma in school children of 6-13 years of age in Shimla city. Indian J Chest Dis Allied Sci 2010;52:145-8.
24. Jain A, Vinod Bhat H, Acharya D. Prevalence of bronchial asthma in

rural Indian children: A cross sectional study from South India. Indian J Pediatr 2010;77:31–5.
25. Dhabadi BB, Athavale A, Meundi A, Rekha R, Suruliraman M, Shreeranga A, *et al*. Prevalence of asthma and associated factors among schoolchildren in rural South India. Int J Tuberc Lung Dis 2012;16:120–5.
26. Kumar G, Premarajan KC, Sarkar S, Sahu SK, Sahana, Ambika, *et al*. Prevalence and factors associated with asthma among school children in rural Puducherry, India. Curr Pediatr Res 2012;16:159-63.
27. Mathew AC, Prince TG, Remees R, Saravanapandian N, Ramalingam S, Srikanth K, *et al*. Prevalence and risk factors of asthma in school going children in South India. Nepal J Epidemiol 2012;2:171–8.
28. Cheraghi M, Dadgarinejad A, Salvi S. A Cross-Sectional Study to Find Prevalence and Risk Factors for Childhood Asthma in Pune City, India. ISRN Public Health 2012;2012:e361456.
29. Sharma CM, Bhatia SS, Sharma D, Agrawal RP, Meghwani MK, Kumar B. Prevalence of asthma in school children of rural areas of Kanpur, Uttar Pradesh. J Evol Med Dent Sci 2013;2:5298–301.
30. Kumar GS, Roy G, Subitha L, Sahu SK. Prevalence of bronchial asthma and its associated factors among school children in urban Puducherry, India. J Nat Sci Biol Med 2014;5:59–62.
31. Amir M, Kumar S, Gupta RK, Singh GV, Kumar R, Anand S, *et al*. An observational study of bronchial asthma in 6-12 years school going children of Agra District. Indian J Allergy Asthma Immunol 2015;29:62-6.
32. Arora K, Das RR, Pooni PA, Rustagi R, Singh D. A study of the prevalence and risk factors of asthma in urban schools of Ludhiana, Punjab. Indian J Health Sci 2015;8:104-8.
33. Arun BJ, Anberkar AB, Anirudh AT, Sindhu AP, Nagaraj N. A study on prevalence of bronchial asthma among school children in field practice area of medical college in Central Karnataka. Int J Contemp Pediatr 2015;2:274-8.
34. Kumar R, Nagar JK, Goel N, Kumar P, Kushwah AS, Gaur SN. Indoor air pollution and asthma in children at Delhi, India. Pneumonol Alergol Pol 2015;83:275–82.
35. Qureshi UA, Bilques S, Ul Haq I, Khan MS, Qurieshi MA, Qureshi UA. Epidemiology of bronchial asthma in school children (10-16 years) in Srinagar. Lung India 2016;33:167–73.
36. Rambabu B, Chandran CNM, Prasad AK, Manikyamba D, Kumari A. Study of prevalence and risk factors of bronchial asthma in school children in urban and rural areas of Kakinada. J. Evolution Med Dent Sci 2016;5:1096-9.
37. Kamath SP, Kumar SS, Jain A, Ramakrishna A, Baliga SB. Prevalence of bronchial asthma among school-going children in Mangalore, South India. Indian J Comm Health 2017;29:46-54.
38. Kumar N, Kumar N, Sharma P. Prevalence of bronchial asthma among school children in urban and rural areas and associated risk factors: A cross sectional study from western Uttar Pradesh, India. Int J Med Sci Clin Invent 2017;4:2538–43.
39. Lalu JS, Rakesh PS, Leelamoni K. Prevalence of bronchial asthma and factors associated with it among higher secondary school children in Ernakulam district, Kerala, Southern India. J Family Med Prim Care 2017;6:311-5.
40. Naik PB, Ravikumar P. Study of prevalence of bronchial asthma in school children of 6–12 years of age in rural schools of Tumakuru district. Indian J Allergy Asthma Immunol 2017;31:56-60.
41. Vyankatesh AA, Bharat PS, Kush A. Prevalence of Asthma in School going Children of Semi-Urban Area in the State of Madhya Pradesh. Int J Med. Public Health 2016;7:37-40.
42. Bhalla K, Nehra D, Nanda S, Verma R, Gupta A, Mehra S. Prevalence of bronchial asthma and its associated risk factors in school-going adolescents in Tier-III North Indian City. J Family Med Prim Care 2018;7:1452-7.
43. Kumari V, Jagzape TB. Bronchial asthma: Prevalence and risk factors among children in urban population from Raipur, Chhattisgarh. Indian J Allergy Asthma Immunol 2019;33:45-50.
44. Sen S, Varughese PE, Mohammed Arshad KK, Venkateswaramurthy N, Sambathkumar R. Prevalence of childhood bronchial asthma among school going children in Komarapalayam, Nammakal district, Tamil Nadu, India. Inter J Life Sci Pharma Res 2019;9:70-4.
45. Kaushal R, Bhardwaj P, Goel AD, Shekhar S, Kumar P, Goyal JP. Prevalence of asthma and sleep-related breathing disorder in school-going children. Indian J Community Med 2020;45:539-42.
46. Patra PK, Bhattarai D, Prasad A, Jain H, Ranjan S, Ranjan A. Prevalence and risk factors of asthma among school going children in urban area of North India. J Family Med Prim Care 2021;10:421-6.
47. Varmaghani M, Farzadfar F, Sharifi F, Rashidian A, Moin M, Moradi-Lakeh M, *et al*. Prevalence of Asthma, COPD, and Chronic Bronchitis in Iran: A systematic review and meta-analysis. Iran J Allergy Asthma Immunol 2016;15:93–104.
48. Ghaffari J, Aarabi M. The prevalence of pediatric asthma in the Islamic Republic of Iran: A systematic review and meta-analysis. J Pediatr Rev 2013;1:2-11.
49. Hassanzadeh J, Mohammadbeigi A, Moussavizadeh A, Akbari M. Asthma prevalence in Iranian guidance school children, a descriptive meta-analysis. J Res Med Sci 2012;17:293-7.
50. Becker AB, Abrams EM. Asthma guidelines: The Global Initiative for Asthma in relation to national guidelines. Curr Opin Allergy Clin Immunol 2017;17:99–103.
51. Vilozni D, Hakim F, Livnat G, Ofek M, Bar-Yoseph R, Bentur L. Assessment of airway bronchodilation by spirometry compared to airway obstruction in young children with asthma. Can Respir J 2016;2016:5394876.
52. Patel SP, Järvelin MR, Little MP. Systematic review of worldwide variations of the prevalence of wheezing symptoms in children. Environ Health Glob Access Sci Source 2008;7:57.
53. Dombkowski KJ, Hassan F, Wasilevich EA, Clark SJ. Spirometry use among pediatric primary care physicians. Pediatrics 2010;126:682–7.
54. Zanconato S, Meneghelli G, Braga R, Zacchello F, Baraldi E. Office spirometry in primary care pediatrics: A pilot study. Pediatrics 2005;116:e792-7.
55. Reddel HK, Sawyer SM, Everett PW, Flood PV, Peters MJ. Asthma control in Australia: A cross-sectional web-based survey in a nationally representative population. Med J Aust 2015;202:492–7.
56. Price D, Fletcher M, van der Molen T. Asthma control and management in 8,000 European patients: The REcognise Asthma and LInk to Symptoms and Experience (REALISE) survey. NPJ Prim Care Respir Med 2014;24:14009.
57. Nathan RA, Thompson PJ, Price D, Fabbri LM, Salvi S, González-Díaz S, *et al*. Taking Aim at Asthma Around the World: Global Results of the Asthma Insight and Management Survey in the Asia-Pacific Region, Latin America, Europe, Canada, and the United States. J Allergy Clin Immunol Pract 2015;3:734-42.e5.
58. Armour CL, Lemay K, Saini B, Reddel HK, Bosnic-Anticevich SZ, Smith LD, *et al*. Using the community pharmacy to identify patients at risk of poor asthma control and factors which contribute to this poor control. J Asthma 2011;48:914–22.