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%), I² = 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

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] 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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Studies conducted to estimate the prevalence of asthma among children in India have reported a varied prevalence (2–18.2%). 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, 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. 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](image)
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 in STATA 14.0 (Stata Corp LP, College Station, TX, USA) using a random-effects model, weighted by the inverse of the variance. F 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 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.[32]

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            | School        | School           | 5,16      | Modified ATS and BMRC             |
| Gupta et al.[19]   | 2001 | Chandigarh, Haryana  | Rural         | School           | 9,20      | Modified IUATLD                   |
| Chakravarthy et al.[20] | 2002 | Chengalpett and Chennai, Tamil Nadu | Mixed** Community | School | 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                     |
| Cherughil 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.[37]   | 2016 | Multicentric         | Mixed         | School           | 6,7 & 13,14 | ISAAC                     |
| Kamath et al.[38]  | 2017 | Mangalore, Karnataka | Urban         | School           | 6,15      | ISAAC                             |
| Kumar et al.[39]   | 2017 | Meerut, Uttar Pradesh | Mixed         | School           | 6,13      | Modified ISAAC                    |
| Lalu et al.[40]    | 2017 | Ernakulam, Kerala    | Mixed         | School           | 16,19     | Modified IUATLD                   |
| Naik & Ravikumar[41] | 2017 | Tumakuru, Karnataka  | Rural         | School           | 6,12      | ISAAC                             |
| Vyankatesh et al.[42] | 2017 | Bhopal, Madhya Pradesh | Urban         | School           | 12,17     | Modified ISAAC                    |
| Bhatla et al.[43]  | 2018 | Rohtak, Haryana      | Urban         | School           | 11,16     | ISAAC                             |
| Gupta et al.[44]   | 2018 | Jaipur, Rajasthan    | Urban         | School           | 5,15      | Modified ISAAC                    |
| Kumari and Jagzap[45] | 2019 | Raipur, Chhattisgarh | Urban         | Community        | 6,14      | ISAAC                             |
| Sen et al.[46]     | 2019 | Namakkal, Tamil Nadu | Urban         | School           | 12,15     | ISAAC                             |
| Kaushal et al.[47] | 2020 | Jodhpur, Rajasthan   | Mixed         | School           | 6,7 & 13,14 | ISAAC                     |
| Patra et al.[48]   | 2021 | Patna, Bihar         | Urban         | School           | 6,16      | Modified ISAAC                    |
| Rashmi et al.[49]  | 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.

| Study                          | ES (95% CI) | Weight (%) |
|-------------------------------|------------|------------|
| School                        |            |            |
| Chiabara et al. (1998)        | 15.7 (14.3, 17.2) | 3.90 |
| Chhabra et al. (1999)         | 15.3 (14.8, 15.8) | 3.90 |
| Gupta et al. (2001)           | 2.3 (2.0, 2.6) | 3.95 |
| Awasthi et al. (2004)         | 2.8 (2.4, 3.2) | 3.94 |
| Pahale et al. (2006)          | 10.7 (9.7, 11.8) | 3.93 |
| Bhat et al. (2010)            | 2.3 (1.4, 3.4) | 3.85 |
| Dhabadi et al. (2012)         | 4.9 (3.3, 7.0) | 3.76 |
| Kumar et al. (2012)           | 8.7 (6.7, 12.7) | 3.55 |
| Mathew et al. (2012)          | 8.5 (7.2, 10.0) | 3.89 |
| Cheregi et al. (2012)         | 8.7 (5.9, 7.5) | 3.93 |
| Shams et al. (2013)           | 8.8 (8.9, 8.9) | 3.95 |
| Kumar et al. (2014)           | 5.3 (2.9, 8.8) | 3.54 |
| Amir et al. (2015)            | 7.0 (6.0, 8.1) | 3.91 |
| Avora et al. (2015)           | 7.5 (6.4, 8.7) | 3.90 |
| Arun et al. (2015)            | 4.8 (3.2, 6.6) | 3.75 |
| Singh et al. (2016)           | 5.7 (5.6, 5.9) | 3.96 |
| Kamath et al. (2017)          | 6.3 (4.9, 8.0) | 3.84 |
| Kumar et al. (2017)           | 11.0 (9.3, 12.8) | 3.87 |
| Lalu et al. (2017)            | 9.9 (7.6, 12.5) | 3.77 |
| Nai & Rinkumar (2017)         | 3.1 (2.3, 4.0) | 3.89 |
| Vyas et al. (2017)            | 13.9 (10.5, 18.1) | 3.62 |
| Bhal et al. (2018)            | 13.9 (11.5, 15.0) | 3.83 |
| Gupta et al. (2018)           | 10.2 (8.6, 11.8) | 3.92 |
| Ben et al. (2019)             | 10.5 (8.5, 12.4) | 3.84 |
| Kaushal et al. (2020)         | 8.0 (6.9, 9.2) | 3.91 |
| Patra et al. (2021)           | 2.8 (2.0, 4.0) | 3.86 |
| Subtotal (I² = 99.2%, p = 0.0) | 7.6 (5.8, 9.6) | 100.00 |
| Community                     |            |            |
| Chakravarty et al. (2002)     | 10.0 (15.5, 20.6) | 14.40 |
| Jain et al. (2010)            | 10.3 (7.5, 13.1) | 14.24 |
| Kumar et al. (2015)           | 7.9 (7.0, 8.9) | 14.84 |
| Qureshi et al. (2016)         | 6.0 (5.3, 8.9) | 14.46 |
| Ramchand et al. (2016)        | 15.0 (12.8, 17.3) | 14.96 |
| Kumar and Jagade (2019)       | 5.1 (2.4, 8.5) | 12.89 |
| Raheem et al. (2021)          | 2.0 (1.2, 3.1) | 14.52 |
| Subtotal (I² = 97.1%, p = 0.0) | 8.7 (5.1, 13.1) | 100.00 |
| Heterogeneity between groups: p = 0.634 |            |            |
| Overall (I² = 99.1%, p = 0.0); | 7.9 (6.3, 9.6) |            |

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 I² 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.[7] | 1998 | 2609          | 16.5              | 14.8               | 15.7*                         |
| Chhabra et al.[8] | 1999 | 18,955        | 16.6              | 13.7               | 15.3*                         |
| Gupta et al.[9]  | 2001 | 9090          | 2.6               | 1.9                | 2.3                           |
| Chakravarthy et al.[20] | 2002 | 855           | NA                | NA                 | 18                            |
| Awashti 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                           |
| Artun et al.[33] | 2015 | 550           | 5.1               | 3.8                | 4.5                           |
| Kumar et al.[34] | 2015 | 3104          | NA                | NA                 | 7.9                           |
| Qureshi et al.[35] | 2016 | 806           | 8.3               | 6.6                | 7.4                           |
| Ramabubu et al.[36] | 2016 | 989           | 17.7              | 12.7               | 15                            |
| Singh et al.[37] | 2016 | 44,928 and 48,088 (93,016) | NA       | NA                 | 5.4 and 6.1 (5.7)             |
| Kamath et al.[38] | 2017 | 1011          | NA                | NA                 | 6.3                           |
| Kumar et al.[39] | 2017 | 1287          | 10.3              | 12                 | 11                            |
| Lalu et al.[40]  | 2017 | 629           | NA                | NA                 | 9.9                           |
| Naik & Ravikumar[41] | 2017 | 1631          | 3.4               | 2.8                | 3.1                           |
| Vyankatesh et al.[42] | 2017 | 331           | NA                | NA                 | 13.9                          |
| Bhalia et al.[43] | 2018 | 927           | 19                | 7.6                | 13.1                          |
| Gupta et al.[44] | 2018 | 2925          | NA                | NA                 | 18.2                          |
| Kumari and Jagzape[45] | 2019 | 175           | NA                | NA                 | 5.1                           |
| Sen et al.[46]   | 2019 | 991           | NA                | NA                 | 10.3                          |
| Kaushal et al.[47] | 2020 | 380 and 1865 (2245) | NA       | NA                 | 6.6 and 8.3 (8)               |
| Patra et al.[48] | 2021 | 1163          | 3.1               | 2.6                | 2.8                           |
| Rashmi et al.[49] | 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.[19] 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...
| 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            | No             | Yes         | No          |
| 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           | Yes                 | No             | No             | Yes         | No          |
| 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           | Yes          | No          | Yes        | No          | No         |
| 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           | Yes           | Cannot say   | Yes         | Yes        | Yes         | Yes        |
| Was a satisfactory response rate achieved?                             | Yes           | Yes         | Yes          | Yes           | No           | Yes         | 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           | No             | Yes          | No          | Yes        | No          | No         |

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

| Question                                                                 | Bhalla et al | Gupta et al | Kumari and Jagzape et al | 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                       | Yes     | No            | Yes        | Yes         |
| Could the way the sample was obtained introduce (selection) bias?      | No           | No          | No                        | No      | Cannot say   | 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         |
| 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           | Yes        | 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          |
Our study findings resonate with a qualitative review done by Pal et al. 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. 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 in 2013 and Hassanzadeh et al. 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 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 variability in symptoms, and the presence of other respiratory conditions such as pneumonia or bronchiolitis.

Figure 4: Forest plot of the meta-analysis for the prevalence of asthma by study setting (school-based studies)
Improvement in spirometry readings following bronchodilator is more sensitive in children and is vital to help confirm a diagnosis of asthma.\cite{4} Epidemiological data is based mainly on questionnaire-reported symptoms, which may not always be accurate, resulting in variations in the prevalence rates of asthma.\cite{5} 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.\cite{6} Another study reported that 21% of spirometry values were misinterpreted,\cite{7} 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.

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