



Prevalence and Risk Factors of Soil-Transmitted Helminthic Infections in the Pediatric Population in India: A Systematic Review and Meta-Analysis

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Abstract

Soil-transmitted helminths (STH) is a major healthcare challenge in the pediatric age group affecting poor and deprived parts of our community. The main species that infect people are roundworm (AL, *Ascaris lumbricoides*), whipworm (TT, *Trichuris trichiura*), and hookworms (HW, *Ancylostoma duodenale* and *Necator americanus*). We aimed to estimate the pooled prevalence of STH infections in India in the pediatric age group (< 18 years) and assess the risk factors associated with STH in this age group. Three databases were searched (PubMed, Scopus, and Embase) up to February 16, 2021 with deliberate and inclusive search terms for original research articles estimating the prevalence of either of the three STH in India. Data extracted included individual prevalence of the three STH, prevalence of double or triple infections, and associated risk factors.

We identified systematically 1,408 publications, of which 44 were included for the final analysis, including studies from 20 states covering 34,590 children. In our study, the prevalence of AL ranged from 0.8 to 91% with a pooled prevalence of 25%, prevalence of TT ranged from 0.3 to 72% with a pooled prevalence of 13%, and for HW prevalence ranged from 0.2 to 80% with pooled prevalence of 10%. Two most important risk factors with higher odds ratio were open defecation practices or open latrine (odds ratio: 5.2) and washing hands without soap using water only (odds ratio: 2.49). Knowledge of areas with high prevalence of STH and associated risk factors would help in designing effective control strategies in the high-risk groups to prevent infection and aid in a drastic reduction of morbidity in children.

Keywords

- ▶ *Ascaris*
- ▶ hookworm
- ▶ prevalence
- ▶ soil-transmitted helminth
- ▶ *Trichuris*

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Introduction

Soil-transmitted helminths (STH) contribute significantly to intestinal helminthic infections and is a major healthcare challenge in pediatric age group. The main species that infect people are the roundworm (AL, *Ascaris lumbricoides*), the whipworm (TT, *Trichuris trichiura*), and hookworm (HW, *Ancylostoma duodenale* and *Necator americanus*). They constitute those nematodes/roundworms that are transmitted through soil contaminated with fecal matter. Adult worms live in the intestine and produce thousands of eggs every day. STH infections are transmitted by eggs and larvae present in human feces that contaminate soil in areas with poor sanitation. Roundworm and whipworm eggs are infective, whereas HW egg has to develop in larval form to be infective to humans. The eggs are ingested while consuming fruits and vegetables that are not properly washed or cooked or from contaminated water sources or due to poor hygiene of children who come more often in contact with soil and put hands in their mouth. The eggs of HW hatch in the soil and release larvae that mature into a form that actively penetrates the skin to cause infection. Therefore, people who have habit of walking barefoot on contaminated soil are more prone to HW infection. The preschool-aged children, school-aged children, and women of childbearing age are mainly at high risk of STH infections. Since these worms do not multiply in the human host, reinfection may occur only as a result of contact with infective stages in the environment. STH can be diagnosed by examination of stool sample using microscope for the presence of eggs. The risk of STH infection cannot be linked with any one factor because of coexistence and combined effect of multiple factors including environmental, behavioral, social, and biological, both at individual and community level.

STH infections are a major public health problem in tropical and subtropical countries affecting the poor and deprived parts of the community. Around 1.5 billion people globally are infected with STH infections. Worldwide 819 million people approximately are infected with *Ascaris*, 464 million with *Trichuris*, and 438 million with HW. More than 267 million preschool children and over 568 million school going children live in areas with increased transmission of these infections and thus are in need of preventive measures as well as treatment.¹ Asia contributes to almost 70% of the global prevalence of STH and within Asia the highest prevalence is seen in India (21%) followed by China (18%).^{2,3} Infection is generally most prevalent among rural communities in warm and humid equatorial regions and where sanitation facilities are inadequate. However, infection can also occur in urban areas. Disability-adjusted life years caused by STHs are 5.2 million, and the majority 3.23 million (62%) are attributable to HW.⁴

To control the STH infections, it is important to target the high-risk population as well as areas where the prevalence is high. It can be achieved by periodic treatment that can reduce the intensity of infection of at-risk population living in these endemic areas. The World Health Organization

(WHO) recommends periodic treatment with antihelmintics, without any previous diagnosis to all the at-risk people living in endemic areas. In 2018, more than 676 million school-aged children were given antihelmintics medicines in endemic countries that correspond to 53% of all children at risk.¹ Along with deworming, STH infections can be prevented by educating the community on healthy and hygienic practices and provision of access to basic sanitation facilities, though that may sometimes be difficult specially in resource poor settings.

With an objective of deworming all preschool and school-aged children between 1 and 19 years of age through schools and Anganwadi centers, the Ministry of Health and Family Welfare, Government of India launched the National Deworming Day on February 10 each year. The first round of this was conducted in February 2015.

Although previous studies or reviews are available on prevalence of STH in India, none of them conducted a meta-analysis and that too in children, the group that is at higher risk. Due to the high morbidity caused by STH infections, we intended to review, assess, and synthesize the literature on prevalence and risk factors of the three STH infections among children (< 18 years) in India. To the best of our knowledge, this is the first systematic review and meta-analysis addressing both the prevalence and risk factors of STH infections in the Indian context in this age group. This study will help in identifying the areas most affected with STH infections and identification of the most important risk factors to develop targeted prevention strategies.

Objective

We aimed to conduct a systematic review and meta-analysis to estimate the pooled prevalence of STH infections in India in pediatric age group (< 18 years). Our secondary objective was to assess the risk factors associated with STH in this age group.

Methods

This review was conducted in accordance with “Preferred Reporting Items for Systematic reviews and Meta-analysis–Protocols” (PRISMA-P)⁵ and the “Meta-analysis of Observational Studies in Epidemiology” (MOOSE)⁶ guidelines.⁶ This study was registered with the International prospective register of systematic reviews “PROSPERO” [Registration no. CRD42021234126].

Eligibility Criteria

Criteria were established for eligibility of articles in the review before beginning the search.

Inclusion Criteria

All community-based observational studies reporting the prevalence of at least one STH among children (0–18 years) in India were included. *Ascaris* (AL), *Trichuris* (TT), and HW (*Ancylostoma* mostly found in India) were the three STH for which prevalence was noted.

Exclusion Criteria

Case reports, clinical/intervention studies, hospital-based studies, and review articles were excluded. Only community-based studies were included where the subjects were not having any previous diagnosis. Moreover, articles that were not fully accessible were excluded because of the inability to assess the quality of articles in the absence of full text.

Search Strategy and Data Extraction

Three databases were searched (PubMed, Scopus, and Embase) up to February 16, 2021 to do the literature search with the following search terms: (prevalence or incidence or epidemiology or risk factor or causal factor) and (helminth or STH or *Ascaris* or *Trichuris* or HW) and (India or Indian) and (pediatric or child or kid or baby). The reference lists of relevant articles obtained were screened for its suitability to be recruited into this review. No filters were used. Duplicates were removed. Two authors (PC and SS) independently conducted the search and screened the study title and abstract. The studies selected after screening the title and abstract were then screened further by full text selection. For articles related to the prevalence of STH—any one or all three, AL or TT or HW in the title and/or abstract, the full text was assessed further. Full-text selection was done with approval of both the authors. Disagreements during full-text selection were resolved by discussion and reaching consensus in the presence of third author (VKD).

The two authors (PC and SS) extracted the data and performed quality assessment of included studies using Microsoft Excel. One of the reviewers recorded the data from the selected studies into the extraction form using Excel, while the second reviewer verified the accuracy and completeness of the extracted data. Data was extracted under the headings: first author, year of publication, place, author of the study, age of study subjects, setting, month and year in which it was conducted, duration of the study, type of study, individual prevalence of the three STH, prevalence of double or triple infections, and the stool processing method used. The associated risk factors with the number of cases infected and not infected with STH both in exposed and nonexposed groups were noted. In studies where all age groups were included, data for pediatric age group was extracted and rest were excluded. For studies with multiple intestinal parasites, data for the STH (any available or all three) was extracted.

Quality Assessment:

The studies were assessed for the methodological quality based on the tool developed by Wong et al also used in a few other studies.^{7,8} The checklist quality assessment tool for systematic reviews of observational studies (QATSO) (►Supplementary Table S1) was used to assess the quality of searched articles by two independent investigators (PC and SS). The tool consists of 6 items that assess components in observation studies and whenever the information provided was not enough to assist in making judgement for a certain item, we agreed to grade that item with a “0” meaning high risk of bias. Each article’s quality was graded as “good” if

the score was 5 or 6 out of 6; or graded as “satisfactory” if the score was 3 or 4 out of 6, and “poor” if the score was 0, 1, or 2 out of 6. The studies were not excluded on basis of their quality.

Ethical approval was not required in this review as the work consisted of secondary data collection and analysis.

Data Analysis:

The analysis was done by STATA/se Version 13.0 statistical software. We presented results with tables and forest plots. The pooled prevalence of each STH was estimated with a random effect model by generating the pooled 95% confidence interval (CI) using the Der Simonian and Laird’s methods. Heterogeneity among studies was assessed by calculating p -values for Higgins I^2 - statistics. I^2 index (low is < 25%, moderate 25–50%, and high > 50%) indicated the percent of total discrepancy due to variation between the studies. The risk factors for STH infection were reported in odds ratio (OR) with 95% CI by using a random effect model. Begg’s funnel plot was used for evaluating the possibility of publication bias (►Supplementary Fig. S1).

Results:

Literature Searches and Selection

We identified systematically 1,408 publications, of which 44 were included for the final analyses. The details of our search strategy are depicted in ►Supplementary Table S2 and the flow of selection of studies for the review is shown in ►Fig. 1. Our initial search of electronic databases such as PubMed, Scopus, and Embase yielded 1,388 articles and 20 articles from other sources including extensive search of references of studies. Out of 1,408 articles, 436 were found to be in duplicate and were removed. Further on the basis of title and abstract, 861 articles were excluded. These were not found suitable according to our inclusion criteria. From the remaining studies that were selected, 48 full-text articles could not be obtained and had to be excluded. Sixty-three studies were initially selected. Full text for each of these 63 studies was read carefully. Nineteen articles were further excluded due to various reasons. Two were hospital-based/intervention studies, five had no separate data for pediatric population, three were lacking data for STH, and nine had to be excluded due to different reasons like data discrepancy in text and tables of articles. Finally, 44 articles published between 1968 and 2020 fulfilling the inclusion criteria were included. These studies reported the prevalence of at least one STH among pediatric age group in India.

The characteristics of selected studies included in systematic review and meta-analysis are shown in ►Table 1. The sample size of the included studies ranged from 52⁹ to 6,421¹⁰ with a total number of 34,590 participants for which stool samples were examined for the presence of one or more intestinal parasites. Data specifically matching our inclusion and exclusion criteria was extracted. Total of 18 studies had the data of prevalence for all three STH, 21 studies had data for at least two parasites, 2 studies had data only for AL, 1 only for TT, and 2 only for HW. For stool examination, the

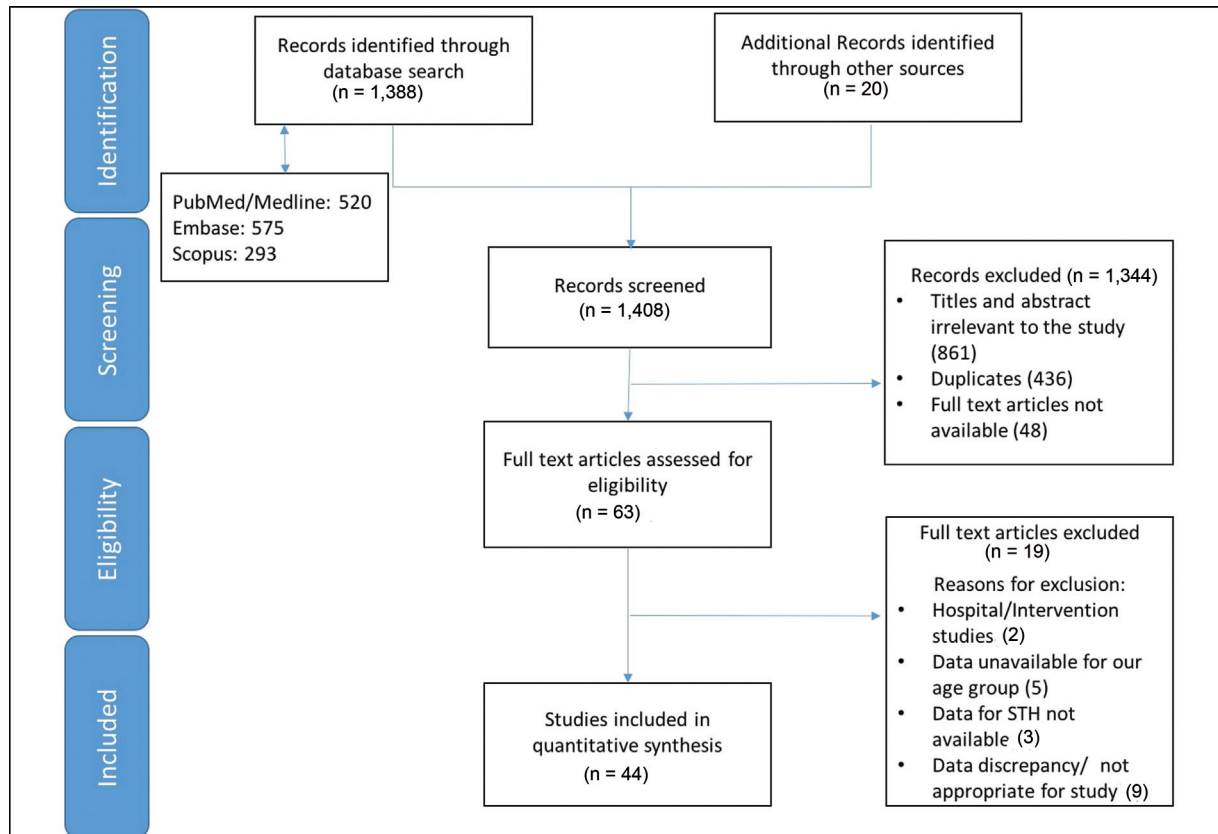


Fig. 1 Flowchart of selection of studies for the review. STH, soil transmitted helminths.

researchers in the given studies used direct microscopy by wet mount (saline and iodine), Kato-Katz technique and microscopy after stool concentration with methods like salt flotation, formol ether concentration, mini-FLOTAC, and zinc sulphate for parasite detection. Maximum number of studies, 18 (42% of the studies) were from North India, of which 8 were from Jammu and Kashmir, 3 from Delhi, 4 from Uttar Pradesh, 2 from Uttarakhand, and 1 from Haryana. From Northeast 3 (6.8%) studies were included, 2 from Sikkim, and 1 from Assam. In the central India only, two (4.5%) studies were included, one each from Chhattisgarh and Madhya Pradesh. Five (12.5%) studies were from Eastern India, three from West Bengal and one from Bihar and Orissa each. One of the studies was partly carried out in Uttar Pradesh and partly in Jharkhand. From the west part of India, 4 (9.1%) studies were included, two from Gujarat and one from Maharashtra and Rajasthan each. From the southern part of India, 11 (25%) studies were included, five from Tamil Nadu, three from Andhra Pradesh, two from Karnataka, and one from Puducherry. Children from all age groups 0 to less than 18 years were included in the studies.

Quality Assessment

According to our quality assessment criteria, 32 publications out of 44 had score 3 or 4 indicating they were of moderate quality, 10 had a score of 5 or 6 indicating high quality, and the remaining 2 were of low quality with a score of zero or one or two. The results of quality assessment of studies are shown in ► **Supplementary Table S3**.

Population Characteristics

A total of 34,590 children from different studies were included in this analysis. Twenty-nine out of 44 studies (66% of total studies) were done on school children. The pooled prevalence of AL was estimated to be ($n = 41$ studies) 25% (95% CI: 16–35%) with substantial heterogeneity ($I^2 = 99.7\%$, $p < 0.05$); for TT ($n = 31$ studies) 13% (95% CI: 8–18%) with substantial heterogeneity ($I^2 = 99.4\%$, $p < 0.05$); and for HW ($n = 29$ studies) 10% (95% CI: 4–18%) with substantial heterogeneity ($I^2 = 99.6\%$, $p < 0.05$). Prevalence of double infections ($n = 12$ studies) was 11% (95% CI: 7–25%) with substantial heterogeneity ($I^2 = 99.09\%$, $p < 0.05$), triple infection ($n = 4$ studies) 1% (95% CI: 0–4%) with substantial heterogeneity ($I^2 = 97.0\%$, $p < 0.05$). Forest plots of pooled prevalence are given in ► **Fig. 2**. Prevalence of AL ranged from 0.8 to 91%.¹¹ For TT, the prevalence ranged from 0.3¹² to 72%.¹¹ For HW, the prevalence ranged from 0.2¹³ to 80%.¹⁴ Regional distribution of the three STH has been plotted in ► **Figs. 3–5**.

Pooled prevalence from studies in different parts of India is as shown in ► **Supplementary Table S4**. Maximum prevalence of AL was seen in Northeast and northern parts of India that are 46 and 35%, respectively. TT was found to be maximum in southern India and constituted 19% of the study population. Highest prevalence of HW was seen in eastern part of India (49%).

Risk Factors Analysis

Risk factors associated with STH were analyzed in this meta-analysis. Though previous studies reported association of

Table 1 Characteristics of selected studies included in the systematic review and meta-analysis (N = 44)

Sl no.	Author/year	Study design	Study duration	Setting	Location	Sample size	Age group (y)	STH%					Technique
								AL	TT	HW	Double inf	Triple inf	
1	Narain et al/2000 ²⁵	Cross sectional	1996–1998	Village	Dibrugarh, Assam	168	0–10	–	26.8	–	–	–	Formalin–ether concentration
2	Subba and Singh/2020 ¹²	Cross sectional	Jan 2016–Dec 2016	School children	East Sikkim	300	5–18	3	0.3	Nil	–	–	Saline and Iodine mount, formalin ether concentration
3	Devi/2009 ¹⁵	Cross sectional	Feb 2008–Sep 2008	School children	Dibrugarh, Assam	1029	5–13	63	19	1.7	–	–	Direct smear and formalin ether concentration
4	Wani and Ahmad/2009 ²⁶	Cross sectional	April 2007–Oct 2007	School children	Pulwama, Jammu & Kashmir	199	5–14	69.8	31.6	Nil	–	–	Direct smear and zinc sulphate floatation concentration
5	Wani and Amin/2016 ²⁷	Cross sectional	May 2013–Nov 2013	School children	Shopian, Jammu & Kashmir	352	4–15	71.8	26.4	Nil	–	–	Direct smear and zinc sulphate floatation concentration
6	Wani et al/2008 (a) ²⁸	Cross sectional	May 2006–Nov 2006	School children	Anantnag, Baramulla, Budgam, Kupwara, Pulwama, and Srinagar, Jammu & Kashmir	382	5–15	63	54	Nil	39.26	–	Direct smear and zinc sulphate floatation concentration
7	Lone et al/2011 ²⁹	Cross sectional	May 2009–Nov 2009	School children	Budgam, Jammu & Kashmir	396	3–14	54.9	32.5	Nil	–	–	Formalin ether concentration, Kato-Katz smear
8	Wani et al/2007 (a) ³⁰	Cross sectional	April 2006–Oct 2006	School children	Srinagar Jammu & Kashmir	514	5–14	28.4	4.9	Nil	–	–	Direct smear and zinc sulphate floatation concentration & stall egg counting technique
9	Wani et al/2008 (b) ³¹	Cross sectional	March 2007–Nov 2007	Children from rural and urban areas	Anantnag, Baramulla, Budgam, Kupwara, Pulwama, and Srinagar, Jammu & Kashmir	2256	0–15	68.3	27.9	Nil	1.8	–	Direct smear and zinc sulphate floatation concentration
10	Wani et al /2010 ³²	Cross sectional	July 2008–October 2008	School children	Gurez valley, Bandipora, Jammu & Kashmir	352	1–15	71.8	26.4	Nil	–	–	Simple smear and Kato-Katz thick smear
11	Wani et al/2007(b) ³³	Cross sectional	Aug 2016–Sep 2016	Children from ICDS center	Kupwara, Jammu & Kashmir	312	4–15	69.23	30.76	Nil	22.1	–	Direct smear and zinc sulphate floatation concentration
12	Das et al/2019 ⁹	Cross sectional	Aug 2016–Sep 2016	Children from ICDS center	Darjeeling, West Bengal	52	0.5–6	7.7	1.9	Nil	–	–	Direct smear and zinc sulfate floatation and formalin-ether concentration

Table 1 (Continued)

Sl no.	Author/year	Study design	Study duration	Setting	Location	Sample size	Age group (y)	STH%					Technique		
								AL	TT	HW	Double inf	Triple inf			
13	Chowdhury et al/1968 ¹⁴	Cross sectional	1961–1963	Rural area	Kolkata, West Bengal	261	0–15	–	–	80	–	–	–	–	Direct smear and salt flotation
14	Nawalinski et al/1978 ³⁴	Cross sectional	March 1969–Dec 1970	Rural area	Kolkata, West Bengal	4078	1–11	14	1.8	68.3	–	–	–	–	Martin-Beaver modification of the Kato-katz thick-smear
15	Greenland et al/2015 ¹⁶	Cross sectional	Jan2011–Feb 2011	School children	Araria, Aurangabad, Muzaffarpur and Gopalganj, Bihar	1157	4–17	52	5	42	26.7	1.8	–	–	Modified Kato-Katz
16	Mahapatra et al/2020 ¹⁷	Cross sectional	May 2015–Oct 2015	Slum children	Bhubaneswar, Odisha	360	3–15	5.8	Nil	10.5	3.05	–	–	–	Direct smear and Kato-Katz
17	Bora et al/2006 ³⁵	Cross sectional	Aug 2005	Hilly area children	Pauri Garhwal, Uttarakhand	257	9–10	28.8	1.9	5.1	4.3	–	–	–	Modified Kato-Katz
18	Bansal et al/2018 ¹⁸	Cross sectional	–	School children	Rishikesh, Uttarakhand	461	<10	0.8	Nil	2.1	–	–	–	–	Concentration by saturated salt Solution and saline & iodine mount
19	Awasthi et al/1997 ³⁶	Cross sectional	Jan1995–July 1995	Children from anganwadi centers	Lucknow, Uttar Pradesh	1040	1.5-3.5	11.9	–	–	–	–	–	–	Direct smear examination
20	Ganguly et al/2017 ¹⁰	Cross sectional	May 2015–August 2015	School children	Uttar Pradesh	6421	<15	69.6	4.6	22.6	8.1	0.07	–	–	Double Kato-Katz
21	Bisht et al/2011 ³⁷	Cross sectional	June 2008–Dec 2009	Community children	Ghaziabad, Uttar Pradesh	335	1–14	2.3	1.8	1.2	–	–	–	–	Saline and Lugol iodine wet mount and formalin ether concentration
22	Awasthi et al/2008 ²³	Cross sectional	–	Rural area	Sant Ravidas Nagar, Uttar Pradesh and Khunti, Jharkhand	909	0.5–2	32.1	2.6	3.9	–	–	–	–	Formalin–ether concentration.
23	Yunus et al/1979 ²⁴	Cross sectional	1977	School children	Aligarh, Uttar Pradesh	59	5–15	8.5	Nil	11.9	–	–	–	–	Direct smear examination
24	Chandi et al/2018 ³⁸	Cross sectional	–	School children	Durg, Chhattisgarh	250	6–15	19.2	Nil	10.3	–	–	–	–	Saline and iodine wet mount, formalin ether concentration
25	Ranjan et al/2015 ³⁹	Cross sectional	Nov 2012–Jan 2013	School children	Delhi	347	5–15	8.1	3.7	3.7	–	–	–	–	Kato-Katz technique
26	DattaBanik et al/1978 ⁴⁰	Cross sectional	1977	Preschool children of slum area	Delhi	2493	0–5	8.4	1.4	2.7	–	–	–	–	Direct smear

(Continued)

Table 1 (Continued)

SI no.	Author/year	Study design	Study duration	Setting	Location	Sample size	Age group (y)	STH%					Technique
								AL	TT	HW	Double inf	Triple inf	
27	Gupta et al/2020 ¹⁹	Cross sectional	Jan 2016–Dec 2016	Community children	Delhi	250	6–14	54.4	4.8	Nil	4.4		Kato-Katz technique
28	Dhaka et al/2020 ⁴¹	Cross sectional		school children	Rohtak, Haryana	300	6–10	14	Nil	5			Direct smear
29	Tripathi et al/2014 ⁴²	Cross sectional	July 2013–August 2013	School children	Bhopal, Madhya Pradesh	300	6–12	9.84	–	4.92			Direct smear examination
30	Choubisa et al/2012 ⁴³	Cross sectional	Oct 2011–Sept 2011	Bhil tribe	Udaipur, Rajasthan	120	0–15	5.8	Nil	1.6			Formalin ether concentration
31	Shobha et al/2013 ²⁰	Cross sectional	Feb 2008–Dec 2008	Urban slum dweller	Gujarat	518	1–14	2.5	Nil	Nil			Formalin ether concentration
32	Lakhani et al/2012 ⁴⁴	Cross sectional	June 2013–Oct 2013	School children	Vadodra, Gujarat	140	6–12	3.6	0.7	2.1			Formalin ether concentration
33	Naish et al/2004 ¹¹	Cross sectional	Dec 1997–Dec 1998	School children	Vishakhapatnam, Andhra Pradesh	204	5–9	91	72	54			Modified formalin ether sedimentation
34	Paul et al/1999 ⁴⁵	Cross sectional	1993–1994	School children	Vishakhapatnam, Andhra Pradesh	217	7–13	73	66	9	50.7	8	Formalin ethyl acetate sedimentation
35	Rangaiahagari et al/2013 ⁴⁶	Cross sectional	June 2006–August 2006	School children	Amalapuram, Andhra Pradesh	208	5–13	2.9	1.4	5.2	0.96		Formalin ether concentration
36	Aher and Kulkarni/2011 ⁴⁷	Cross sectional		School children	Ahmednagar, Maharashtra	624	6–12	1.9		0.9			Saline and Lugol iodine wet mount
37	Anbumani et al/2011 ⁴⁸	Cross sectional	Jan 2008	School children	Kancheepuram, Tamil Nadu	358	5–10	38.8	13.9	Nil	10		Direct microscopy and saturated sodium chloride floatation
38	Elkins /1984 ⁴⁹	Cross sectional		Different social community	Chennai, Tamil Nadu	491	1–12	60.3	62.3	30.5			Merthiolate iodine formaldehyde Conc Tech, Quant Stoll egg counting technique
39	Kattula et al/2014 ⁵⁰	Case-control	December 2008–August 2009	School children	Vellore, Tamil Nadu	3706	6–14	1.2	0.8	6.3			Saline and iodine wet preparation, match master egg counting screening
40	Gopalakrishnan et al/2018 ⁵¹	Cross sectional	January 2017–March 2017	School children	Kancheepuram, Tamil Nadu	250	13–18	3.2	Nil	4.4			Direct microscopic examination
41	Christu Rajan et al/2020 ¹³	Cross-sectional	Nov 2015–July 2015	School children	Coimbatore, Tamil Nadu	610	5–14	6.9	0.7	0.2			Saline wet mount and iodine wet mount, formalin ether sedimentation

Table 1 (Continued)

Sl no.	Author/year	Study design	Study duration	Setting	Location	Sample size	Age group (y)	STH%					Technique
								AL	TT	HW	Double inf	Triple inf	
42	Ragunathan et al/2010 ²¹	Cross-sectional	March 2006–Sept 2006	School children	Puducherry	1172	5–10	17.5	5.4	12.5	1.8	0.3	Saline and iodine wet preparation, formalin ether sedimentation, Hirada Mori
43	Golia /2014 ⁵²	Cross-sectional	June 2003–Sept 2013	School children	Bangalore, Karnataka	258	6–12	8.1	5.4	1.2			saline and iodine wet mounts, formalin ether sedimentation
44	Panda et al/2012 ²²	Cross-sectional	Dec 2008–Jan 2009	School children	Bangalore, Karnataka	124	6–9	–	–	4.8			Saline and iodine wet mount

Abbreviations: AL, *Ascaris lumbricoides*; HW, hookworm; TT, *Trichuris trichiura*; STH, soil-transmitted helminths.

multiple risk factors with STH and other intestinal parasitic infections, data specific to our inclusion criteria is shown here. The more commonly studied risk factors included gender (10 articles),^{10,13,15–22} place of defecation whether in open or sanitary latrines (7 articles),^{10,13,15–17,23,24} hand washing after defecation with water only or soap and water (6 articles),^{10,13,15–17,23} socioeconomic status (SES) upper and middle versus lower (4 articles),^{10,13,19,24} mother's education (4 articles),^{10,13,16,19} barefoot walking (4 articles),^{13,17,19,24} recent deworming (4 articles),^{10,13,17,19} hygiene of finger nails (3 articles),^{13,19,24} flooring earthen or cemented (3 articles),^{10,13,15} religion (3 articles),^{14,16,19} and hand washing before eating (3 articles).^{13,16,19} OR was calculated and has been given in ►Table 2. For the factors including use of open defecation practices as compared to sanitary latrine, hand washing with water only versus with soap and water after defecation and having an earthen flooring in comparison to cemented flooring had OR more than 2 for getting STH infections. Forest plots for the risk factors associated with STH are as shown in ►Fig. 6. Males and females did not have higher odds over each other for getting STH infections. For the less commonly studied factors (in < 3 studies), OR of more than 2 was obtained in children with presence of anemia,²⁴ pica¹⁹ in comparison to its absence, living in rural area on comparison with staying in urban area,¹⁵ not attending school.¹⁹ Absence of running water in latrine¹⁵ and using a community bin rather than door to door disposal of waste¹⁹ had higher odds of getting STH. Other factors like joint versus nuclear family,^{13,19} father's education,^{17,19} consumption of unwashed fruits and vegetables,¹³ and using tap water over hand pump^{15,23} did not have any association with STH infection and had OR around 1 or less than 1. Having a poor hygiene^{13,19} in terms of not washing fruits and vegetables before eating and eating something that falls on floor and overcrowding¹⁹ had higher odds of STH, 1.87 (95% CI: 0.31–11.37) and 1.83 (95% CI: 1.02–3.26), respectively.

Discussion

STH infections are common cause of morbidity in children of developing countries like India. According to the World Health Organization, around 24% of world population is infected with STH. Two-hundred and forty-one million children between the ages of 1 and 14 years are at risk of parasitic intestinal worms in India. This study covers all the published literature on STH, covering studies from all parts of India in pediatric population (0–18 years). Prevalence percentage of STH is a major determinant of routine deworming practices in a geographical area. The National Deworming Day is an initiative of Ministry of Health and Family Welfare, Government of India to make every child in the country worm-free. It is a large-scale public health program reaching huge number of children in a short period of time. Deworming twice a year is recommended in the states with prevalence of STH more than 20% and once a year in other states with less than 20% prevalence. Calculation of pooled prevalence of STH in pediatric population in different geographical areas of India obtained in this study will help in better implementation of such deworming practices.

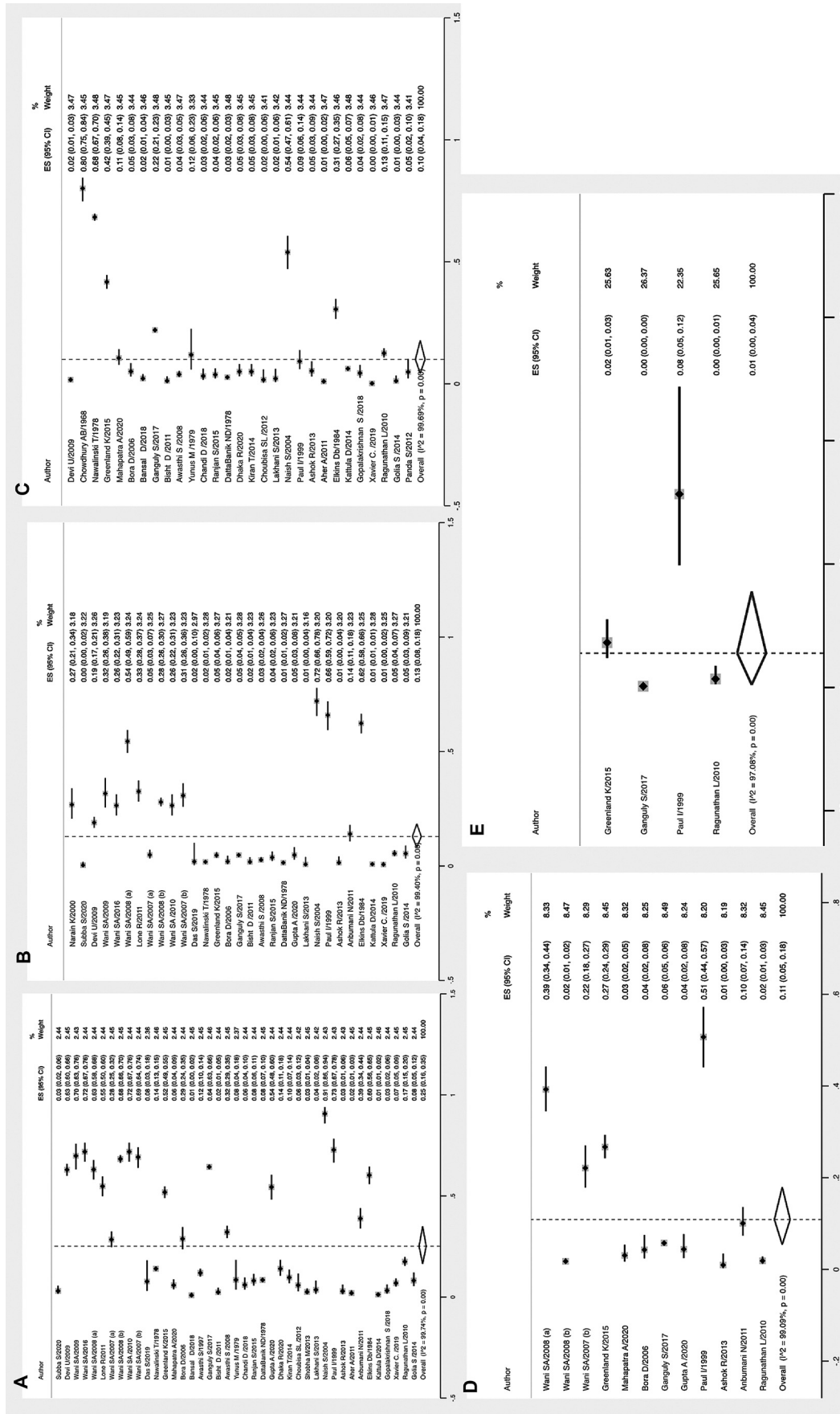


Fig. 2 Forest plots showing pooled prevalence of (A) *Ascaris*, (B) *Trichuris*, (C) hookworm, (D) double soil transmitted helminthic infection, (E) triple soil transmitted helminthic infection. CI, confidence interval; ES, economic status.



India

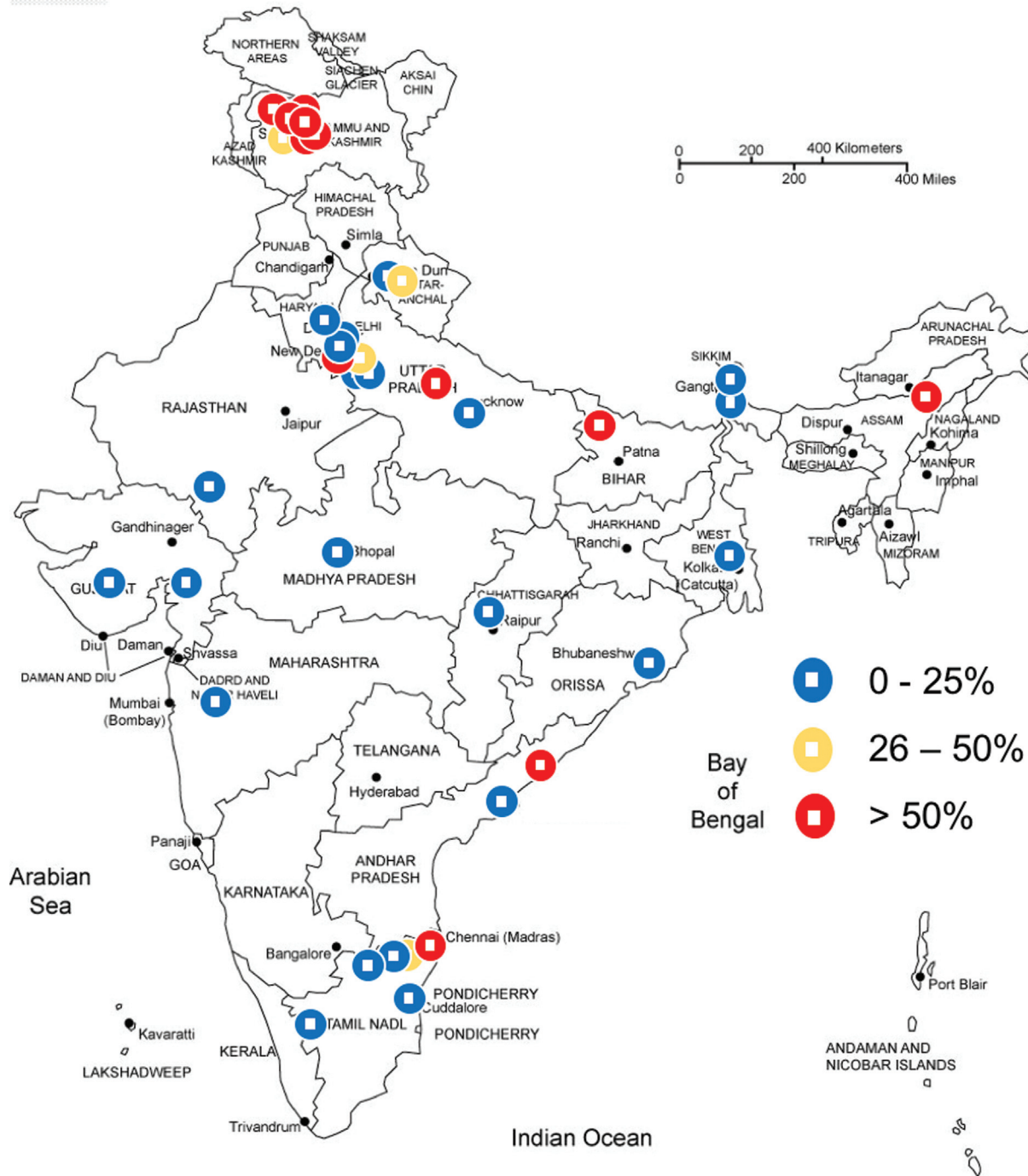


Fig. 3 Map of India showing percentage prevalence of *Ascaris*.

In our study among the three STH, AL was most prevalent. A meta-analysis from South America showed a similar overall high burden of ascariasis.⁵³ In contrast, in a meta-analysis study from sub-Saharan Africa, HW was found to be the commonest STH infection.⁵⁴ In a systematic review published in 2016, the prevalence of AL, *Ancylostoma duodenale* and TT in 18 selected studies in India was in range between 0.4 and 71.87%, 0.14 and 42%, and 0.3 and 29.57%,

respectively.⁵⁵ In our study, the prevalence of AL ranged from 0.8¹⁸ to 91%¹¹ with a pooled prevalence of 25%. For TT, the prevalence ranged from 0.3¹² to 72%¹¹ with a pooled prevalence of 13%. For HW, the prevalence ranged from 0.2¹³ to 80%¹⁴ with pooled prevalence of 10%. Another review was from India by Salam et al 2017,⁵⁶ which aimed to understand the spatial distribution and identify the high-risk zones in India. They included 39 studies from all over India estimating

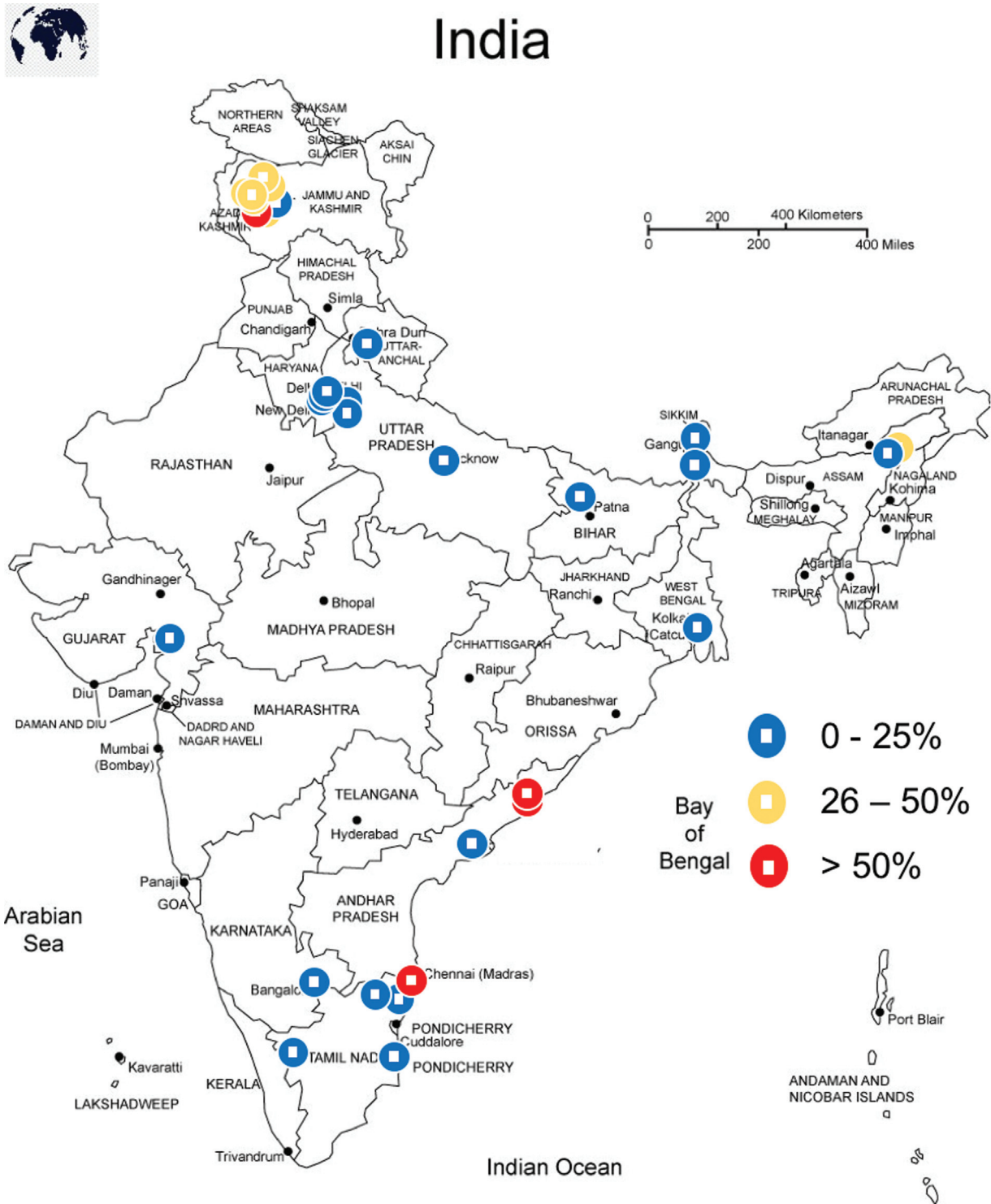


Fig. 4 Map of India showing percentage prevalence of *Trichuris*.

the prevalence of AL infection in the range of 0.6 to 91%, TT in the ranged of 0.7 to 72% and HW ranging from 0.02 to 52%. Our study showed similar results except for HW that ranged from 0.2¹³ to 80%,¹⁴ higher than that reported by Salam et al. However, the previous studies⁵⁵ were done on all age groups as compared to ours that included pediatric population only, which is a better representative of disease burden in more susceptible population at risk.

Our analysis included studies from 20 states/union territories (UT) from India; however, some areas were completely missed due to lack of published literature from those regions. It would be helpful if all the states/UT have their own data to have even more accurate estimate of overall prevalence in those regions as well as India as a whole. Maximum number of studies were from North India and South India. The study selection and data extraction might cause bias in calculation



India

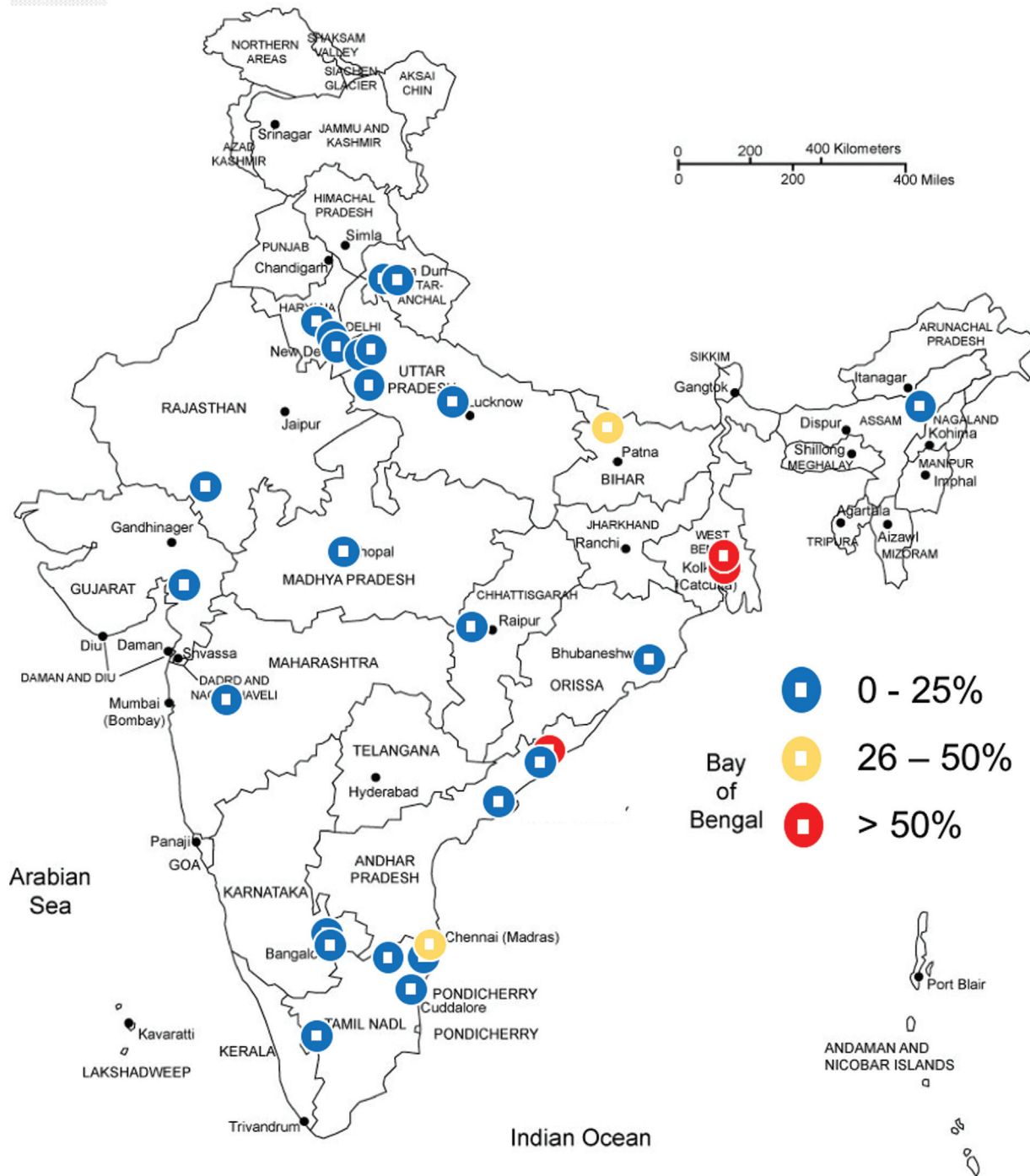


Fig. 5 Map of India showing percentage prevalence of hookworm.

of STH because of this. We tried to include as many studies as possible; however, some of them had to be excluded due to unavailability of full texts. Also, to obtain the prevalence, only community-based studies were selected including subjects who did not have any symptom related to STH. The hospital based or intervention studies were excluded to remove the bias since the symptomatic individuals or those with a previous diagnosis could not be included. The search

strategy was very broad and included broad search query terms. For all the studies that did not report the presence of a particular helminth in an area, it was not clear whether it was not seen in their population or whether they did not look for it. This might have led to under reporting of the prevalence of individual helminths in those cases.

Regional variation in prevalence of the three organisms was seen. Local factors can play a role in their epidemiology.

Table 2 Risk factors associated with STH

Variables	Number of articles	Odds ratio (95% CI)	I ² (%); p-value
Males vs. females	10	1.14 (0.88–1.46)	78; 0.001
Open latrine vs. sanitary latrine	7	5.2 (1.35–20.16)	97.9; 0.001
Hand washing after defecation with water only vs. with soap and water	6	2.49 (1.51–4.12)	92.3; 0.001
SES lower vs. SES upper and middle	4	1.01 (0.74–1.38)	41.1; 0.165
Mother education below primary/illiterate vs. above primary	4	1.07 (0.77–1.47)	72.6; 0.012
Walking barefoot vs. walking with footwear	4	1.73 (0.92–3.28)	61.1; 0.052
Recent deworming negative to recent deworming done	4	1.41 (0.87–2.28)	72.1; 0.013
Nails untrimmed vs. trimmed	3	1.52 (0.43–5.45)	82.5; 0.003
Flooring earthen vs. cemented	3	2.02 (1.33–3.06)	60.2; 0.08
Religion: Hindu vs. other religions	3	1.27 (0.65–2.47)	82.2; 0.004
Poor hand wash habits vs. good hand wash	3	1.55 (0.61–3.92)	92.1; 0.001

Abbreviations: CI, confidence interval; SES, socioeconomic status; STH, soil-transmitted helminths.

Our study gave results similar to the previous data and studies; Western India has the lowest prevalence of all three STH.^{55,56} Pooled prevalence from northern and northeastern India for AL is higher as compared to other two organisms, whereas southern India had higher prevalence for TT. Eastern India had higher prevalence of HW. However, very high heterogeneity between studies as shown by higher I² values restricts us from making conclusive remarks regarding this epidemiology. Overall, prevalence of STH (AL = 25%, TT = 13%, AD = 10%) as found in our study was comparable to other studies in different part of world.⁵⁷ The tropical and subtropical warm climate with humid environment in India provides ideal environment for the survival of parasitic eggs in moist soils. Besides, higher prevalence of STH in regions that are not hot and moist like Jammu and Kashmir^{26–33} points towards role of other factors than climate including socioeconomic and behavioral factors. The unhealthy socio-behavioral habits due to poverty and poor personal and environmental hygiene, underlying socioeconomic factors, underdeveloped sanitation, lack of adequate water supply, increasing population, illiteracy, and poor sociobehavioral habits, and a large section of people living below poverty line play a role in spread of infections as seen from many studies. This meta-analysis includes data from children only as compared to previous studies that had diverse study population including children and adults both. Children in particular are more prone to these infections due to direct contact with soil while playing, poor hygiene, habits of playing or handling of contaminated soils, eating with soiled hands, unhygienic toilet practices, drinking and eating of contaminated water and food, and illiteracy of the care giver or mother. These specific risk factor for children makes them more susceptible to get STH infections that is a major cause of morbidity in pediatric age group. Cumulative OR of the risk factors from different studies calculated in our study would help in designing a better preventive care at different levels. Also, a superior assessment of the risk factors of STH would require meticulous country-specific data, preferably from

nationally representative epidemiological surveys in various communities and geographical areas.

Two risk factors with higher OR were open defecation practices or open latrine (OR: 5.2) and washing hands without soap using water only (OR: 2.49) also point towards poor sanitation services as well as behavior related factors that play a very important role in STH infection in pediatric population. Earthen flooring with OR of 2.2 and walking barefoot with OR 1.73 are also an important risk factor for STH. Other risk factors studied, including sex predisposition (OR: 1.14), economic status (1.01), and mother's education (1.07), were not found to be significantly associated with STH. However, education of parents specially the mother or the caregiver is important in terms of general awareness and knowledge of following hygienic practices. Though pica¹⁹ and anemia²⁴ were two risk factors studied in one study only, they had very high odds of having STH.

The prevalence and estimate of STH burden also depend on the diagnostic method used for the assessment.⁵⁸ Kato-Katz method has been described as the best method by the WHO as reliable diagnostic tool with better efficacy, accuracy, and predictive value than other techniques in resource poor settings. Only 7 out of 44 studies (16%) used Kato-Katz method for detection. Most studies relied upon direct microscopy and concentration techniques as preferred method. Using standard procedure for parasite detection can further increase the sensitivity of studies and help in better understanding of problem. Most of the studies performed only one stool examination, which may result in underreporting of the prevalence. Prevalence and intensity of STH infection are the only tool for preventive chemotherapy and to assess the effect of ongoing deworming program.

The control of STH comes with various challenges like improvement in sanitary conditions and accessibility to safe drinking water. These factors may reduce chances of infection or reinfection, hence decreasing the morbidity in children caused due to STH. In resource-poor settings, educating

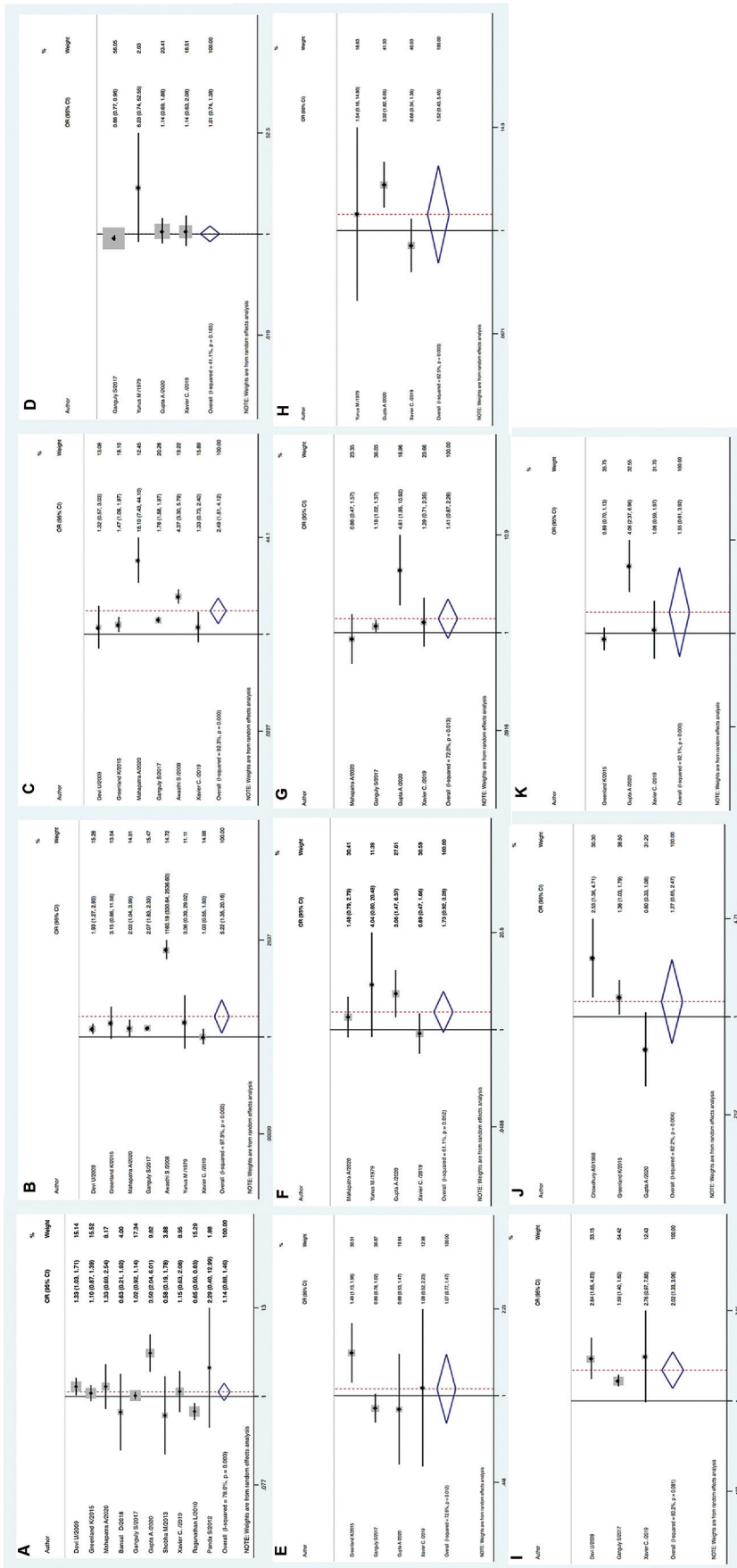


Fig. 6 Forest plots of risk factor analysis for soil transmitted helminthic infection showing odds ratio of (A) Males versus females, (B) Open latrine versus sanitary latrine, (C) Hand washing after defecation with water only versus with soap and water, (D) Socioeconomic status lower versus upper and middle, (E) Mother education below primary/ illiterate versus above primary, (F) Walking barefoot versus walking with footwear, (G) Recent deworming negative to recent deworming done, (H) Nails untrimmed versus trimmed, (I) Flooring earthen versus cemented, (J) Religion: Hindu versus other religions, (K) Poor hand wash habits versus good hand wash. CI, confidence interval; OR, odds ratio.

the people regarding healthy and hygienic practices, implementation, and expansion of mass deworming intervention to all the children can prove to be very effective. Targeting the teachers and caregivers of children for educating the kids about STH, motivating them for a behavioral change and adopting healthy practices such as washing hands with soap and water before handling food products and after using toilet, wearing protective footwear, thorough washing of raw vegetables and fruits with water before eating and sanitary disposal of human excreta can be very useful. These may further amplify the control measures and help to cut down STH transmission.

Conclusion

In our study, we tried to estimate the prevalence of STH in children by analyzing 44 studies from different regions in India. The studies differed from each other due to their heterogeneous sample size, study population, methods used to select, identify parasites, and also the parasites included by them. The pooled prevalence obtained for AL, TT, and HW in India in pediatric population is 25, 13, and 10%, respectively. The risk factors for STH were analyzed. This study may be useful for prevention and control strategies that will help the plan makers to concentrate on the high-risk groups at areas with high prevalence. Also, effective strategies can be designed keeping the most important risk factors in mind.

Authors' Contributions

P.C. and S.S. conceptualized the study. P.C. and S.S. contributed to data extraction. P.C., S.S., and S.P. did formal analysis. P.C., S.S., and V.K.D. were involved in supervision. P.C. and S.S. wrote the original draft. P.C., S.S., V.K.D., and S.P. were involved in writing, review, and editing. P.C., S.S., V.K.D., and S.P. gave approval of final version. All authors read and approved the final manuscript.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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None.

Conflict of Interest

None declared.

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