

Prevalence of Soil-Transmitted Helminth Infection Among School-Aged Children of Ethiopia: A Systematic Review and Meta-Analysis

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ABSTRACT

BACKGROUND: Soil-transmitted helminths (STH) are still major health problems in resource-poor countries. Despite several epidemiological studies were available in Ethiopia, summarized data on the prevalence of STH among school-aged children (SAC) is lacking in the country.

OBJECTIVE: This study was aimed to summarize the existing published studies of STH among SAC children in Ethiopia.

METHODS: The search was carried out in open access databases such as Science Direct, Scopus, and PubMed Central which reported STH in Ethiopia. Open access articles published between 2000 and 2019 were included in this meta-analysis. The pooled prevalence was determined using a random-effect model while heterogeneities between studies were evaluated by I^2 test.

RESULTS: A total of 46338 children (Male = 23374 and Female = 22964) were included in the 70 eligible studies for this meta-analysis. The pooled prevalence of STH among SAC was 33.4%; 95% CI, 29.3% to 37.7% in Ethiopia. *Ascaris lumbricoides* (19.9%; 95% CI, 17.2%-22.6%) was the most prevalent STH followed by *Trichuris trichiura* (12.4%; 95% CI, 10.6%-14.1%), and hookworm (7.9%; 95% CI, 6.9%-8.9%) infection in the country. High prevalence of STH was observed in Oromia (42.5%; 95% CI, 31.6%-53.4%) followed by SNNPR (38.3%; 95% CI, 27.7%-48.8%) and Amhara (32.9%; 95% CI, 27.0%-38.8%) regional states. High heterogeneity on the prevalence of STH was observed across studies within and among regions ($I^2 > 96%$ and $P < .001$).

CONCLUSION: This review showed that more than one-third of the Ethiopian SAC were infected with STH. The high prevalence of STH observed in this review highlight the needs of improved control and prevention strategies in Ethiopia.

KEYWORDS: Meta-analysis, soil-transmitted helminths, systematic review, school-aged children

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Introduction

Soil-transmitted helminths (STH) are a group of Neglected Tropical Diseases (NTD), which is widely distributed in tropical and subtropical regions. STH affect more than 1.5 billion people in tropical regions in Africa, Asia and Latin America.¹ *Ascaris lumbricoides* is the most prevalent STH infecting about 1.2 billion people followed by *Trichuris trichiura* (infecting about 795 million people) and hookworm (*Ancylostoma duodenale* and *Necator americanus*), which infects nearly 740 million people worldwide.^{2,3} The high prevalence of STH in tropical regions is associated with low socio-economic development and suitable environmental conditions that favor the transmission of these helminths.⁴

According to World Health Organization (WHO), 568 million school-age children (SAC) live in areas where STH is intensively transmitted.¹ This indicates that SAC are at higher risk of being infected with STH. These could be associated with the fact that children are more exposed to contaminated soil when they play, walking barefoot, eat soil, and do not have good personal hygiene. It has been reported that the level of sanitation is very poor in developing countries; only 53% of

peoples have access to improved sanitation facilities.⁵ STH are responsible for chronic infections, which may lead to school absenteeism, delayed physical growth and impaired cognitive development, particularly learning, memory intelligence, and reaction time in SAC.⁶

Soil-transmitted helminths is one of the major public health problems in Ethiopia that affect more than 79 million people, of which about 25 million are SAC.⁷ The number of published studies on STH in Ethiopia has been increased in recent years. These epidemiological studies address not only the prevalence of STH but also the potential risk factors. There is a need to summarize the available epidemiological studies systematically to estimate the overall prevalence of STH at the national level and to identify high-risk regions requiring interventions. The WHO aims to control STH infections by 2020 by treating at least 75% of infected children in endemic countries.¹ In line with this, the Ethiopian government launched national mass drug administration (MDA) in November 2015 to reduce STH related morbidity. Such intervention needs a systematical summary of existing published studies to identify target groups and target regions.



Therefore, this review aimed to generate a quality estimate of the pooled prevalence of STH and their regional variations among school-aged children in Ethiopia.

Methods

Search strategies

The search strategies were taking into account the PICO elements (Population, Exposure, Comparison, and Outcome). In this review we focused on population and outcome due to all eligible articles were observational studies. We reported the pooled prevalence of STH among SAC in Ethiopia. In line with this, relevant literatures were systematically searched from 3 online databases (PubMed Central, Scopus, and Science Direct) using the following key-words: “*A. lumbricoides*” OR “*T. trichiura*” OR “hookworm” OR “nematodes” OR “whipworm” OR “roundworm” OR “helminth” OR “soil-transmitted helminths” OR “geohelminths” OR “nematelminths” AND “Ethiopia.” The systematic review and selection of relevant literature were conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guidelines⁸ (Supplemental Table S1).

Selection, inclusion, and exclusion criteria

Literatures published in English language from January 2000 to December 2019 were extracted from online public databases. We include original articles reporting the prevalence of STH (*A. lumbricoides*, *T. trichiura*, and hookworm) from SAC in Ethiopia. Original articles published in English, sample size at least 200 students and number of positive cases clearly stated in the paper were included in this review. Studies that report the prevalence of STH from patients (human immunodeficiency virus, tuberculosis, malaria, and other health complications), pre-school-aged children, and student under-treatment were excluded from the analysis.

Definition of soil-transmitted helminth infection and diagnostic methods

Soil-transmitted helminth infection is a type of helminths infection caused by roundworms (*A. lumbricoides*, *T. trichiura*, and hookworm), which are transmitted by soil contaminated with fecal matter. Several diagnostic methods are available for the detection of STH from patients as well as from the healthy community. However, we selected studies that used better diagnostic approaches namely Kato-Katz thick fecal smear, Mini Parasep concentrator, formal ether concentration, McMaster and Flotach techniques for this systematic review. Kato-Katz thick fecal smear is the WHO recommended technique for the detection of STH infection.⁹

Methods of data extraction and quality assessment

The data extraction protocol was prepared and evaluated by all authors. From each published article we extracted the

following information: study region, sample size, age range, population type (community or patient-based or school-based), study design, diagnostic methods, the prevalence of total STH, and individual species of STH.

Risk of bias assessment of individual articles included

The quality of studies included in the meta-analysis was assessed by using quality assessment tools developed previously for prevalence studies.¹⁰ Studies were assigned either 0 (low risk) or 1 (high risk) for 10 parameters (Supplemental Table S2). The overall quality was determined by adding the assigned number for each parameter and classified as low risk (≤ 2), moderate risk (3-4) or high risk (≥ 5) of bias.

Risk of publication bias across studies included in this meta-analysis

The risks of publication bias across studies were assessed using funnel plot symmetry and Egger's test. The Egger's test *P*-value $< .05$ was used to determine the presence of publication bias across studies.

Statistical analysis

The prevalence of each STH was calculated by dividing the number of STH positive subjects to the total study participants. The heterogeneity among studies used for this meta-analysis was evaluated using inverse variance index (I^2) test.¹¹ I^2 -value lower than 25%, between 25% and 50% and above 50% were regarded as low, moderate, and high heterogeneity, respectively.¹² Because there was an obvious heterogeneity observed among the studies included in the meta-analysis, we used a random-effect model at 95% confidence interval (CI) for estimating the overall effect. To sort out the cause of heterogeneity, we used a subgroup, sensitivity and meta-regression analysis. The meta-analysis was conducted using Stata software (version 14, STATA Corp College Station, TX), where $P < .05$ was considered as statistically significant.

Results

Literature search and selection

A total of 1338 studies that report STH infection in children in Ethiopia were available in an online database. Out of these studies, 875 articles were removed due to duplications while 291 articles were excluded based on title and abstract screening. The remaining 172 full-text articles were assessed for eligibility. Of these, a total of 102 articles were excluded from the analysis based on specific exclusion criteria and 70 articles were selected for this meta-analysis (Figure 1).

Characteristics of the eligible studies

The detailed characteristics of the 70 eligible articles included in the meta-analysis were presented in Table 1. The studies

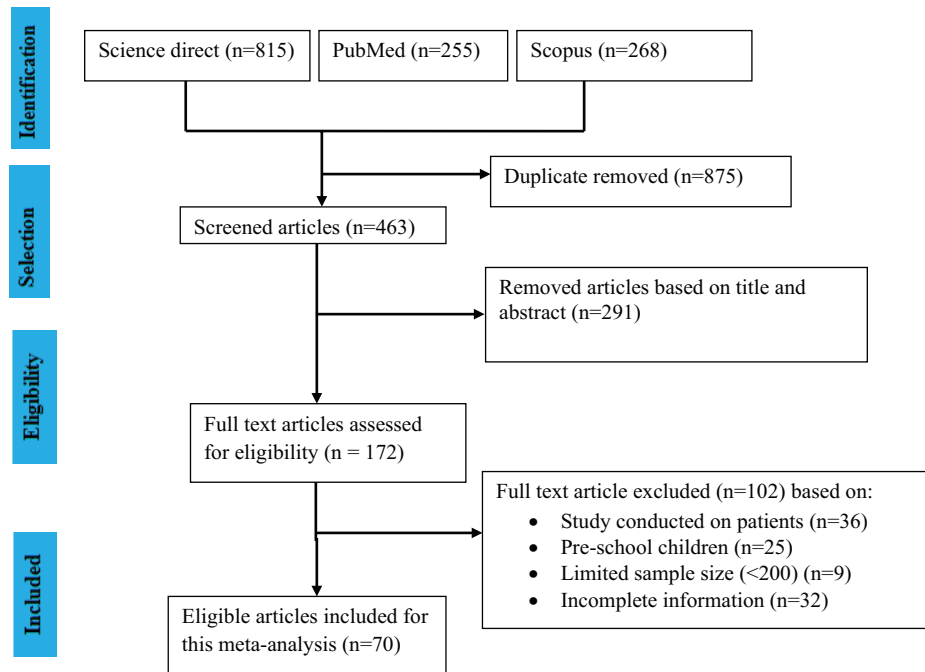


Figure 1. PRISMA flow diagram of publications considered for the review on STH in Ethiopia.

included in this meta-analysis were obtained from 5 regional states; 35.7% from Amhara,¹³⁻³⁷ 24.3% from SNNPR,³⁸⁻⁵⁴ 22.9% from Oromia,⁵⁵⁻⁷⁰ 15.7% from Tigray,⁷¹⁻⁸¹ and 1.4% Benshangul Gumuz⁸² regional states. Unfortunately, there were no studies for other regions and city administrations of Ethiopia that fulfill the inclusion criteria used for this study. All studies included in this review were conducted on SAC (with a minimum age of 5 years) in Ethiopia. The upper age limits of children were not described in some studies.

Risk of bias within individual studies

Among the 70 studies included for this meta-analysis, low risk of bias, moderate risk of bias and high risk of bias were observed on 46 studies (65.7%), 21 studies (30%) and 3 studies (4.3%), respectively (Supplemental Table S2). The overall summary of the risk assessment of all studies included in this meta-analysis showed lower-risk of publication bias across studies.

Prevalence and burden of STH among school-aged children in Ethiopia

A total of 46 338 children (Male = 23 374 and Female = 22 964) were included in the eligible studies. The prevalence of STH was ranged from 3.9% to 82.2% among SAC in Ethiopia. Out of the total 46 338 SAC, 15 477 (33.4%) of them were infected by STH in Ethiopia. The pooled prevalence of STH among SAC was 33.4% (95% CI, 29.3%-37.7%) with substantial heterogeneity ($I^2 = 99.3%$, $P < .001$) in Ethiopia (Figure 2). *Ascaris lumbricoides* was the most prevalent STH 9221 (19.9%; 95% CI, 17.2%-22.6%) followed by *T. trichiura*

5746 (12.4%; 95% CI, 10.6%-14.1%) and hookworm 3661 (7.9%; 95% CI, 6.9%-8.9%) as shown in Supplemental Figures S1-S3, respectively. In addition, the burden of *A. lumbricoides*, *T. trichiura* and hookworm was 9221 (19.9%), 5746 (12.4%), and 3661 (7.9%), respectively in Ethiopia. High heterogeneities on the prevalence of STH were detected between studies included in the meta-analysis ($I^2 > 97%$ and $P < .001$). To sort out the causes of high heterogeneity, we did subgroup analysis and meta-regression.

Sub-group analysis

The sub-group analysis indicates that STH was more prevalent in Oromia (42.5%; 95% CI, 31.6%-53.4%) followed by SNNPR (38.3%; 95% CI, 27.7%-48.8%) and Amhara region (32.9%; 95% CI, 27.0%-38.8%) while low prevalence in Tigray (15.9%; 95% CI, 10.6%-21.1%) and Benshangul Gumuz regional states (Figures 2 and 3). *Ascaris lumbricoides* were more prevalent in SNNPR (26.4%; 95% CI, 18.4%-33.9%), Oromia (23.0%; 95% CI, 16.9%-29.2%), Amhara (18.6%; 95% CI, 14.5%-22.9%) and Tigray (9.6%; 95% CI, 6.3%-12.9%) regions (Supplemental Figure S1). *T. trichiura* infection was more prevalent in Oromia (21.6%; 95% CI, 14.8%-28.4%), Amhara (11.9%; 95% CI, 8.7%-15.1%) and SNNPR (10.1%; 95% CI, 7.3%-12.9%) regional states (Supplemental Figure S2). Similarly, hookworm infection was more common in Oromia (14%; 95% CI, 9.8%-18.2%), SNNPR (9.3%; 95% CI, 6.8%-11.9%) and Amhara (6.1%; 95% CI, 4.8%-7.3%) regional states (Supplemental Figure S3). The prevalence of *T. trichiura* and hookworm were below 3% in Tigray region.

Table 1. Characteristics of the 70 eligible articles included in this review.

YEAR	REFERENCES	REGION	TARGET POPULATION	AGE GROUP	DIAGNOSIS METHOD USED	STUDY PARTICIPANTS			
						TOTAL	POSITIVE	PREVALENCE %	95% CI
2000	Jemaneh ¹³	Amhara	School based	NA	Kato-Katz	687	470	68.4	64.8-71.9
2002	Erosie et al ³⁸	SNNPR	School based	7-25	FECT	421	292	69.4	64.7-73.7
2004	Legesse and Erko ⁵⁵	Oromia	School based	6-25	Kato-Katz and FECT	259	170	65.6	59.5-71.4
2005	Tadesse ⁵⁶	Oromia	School based	5-24	FECT	415	59	14.2	11.0-17.9
2008	Dejene and Asmelash ⁷¹	Tigray	School based	7-19	FECT	800	60	7.5	5.8-9.6
2009	Dejenie and Petros ⁷³	Tigray	School based	5-19	Kato-Katz	2,000	278	13.9	12.4-15.5
2009	Dejenie et al ⁷²	Tigray	School based	Above 6	Kato-Katz	224	147	65.63	59.0-71.8
2010	Legesse et al ⁷⁴	Tigray	School based	6-14	Kato-Katz and FECT	386	28	7.25	4.9-10.3
2011	Alemu et al ¹⁴	Amhara	School based	5-17	Kato-Katz	319	138	43.3	37.8-48.9
2011	Ayalew et al ¹⁵	Amhara	School based	5-15	FECT and Wet mount	704	129	18.3	15.5-21.4
2011	Habtamu et al ⁵⁷	Oromia	School based	5-19	Kato-Katz and FLOTAC	271	158	58.3	52.2-64.2
2011	Terfe et al ³⁹	SNNPR	School based	6-19	Kato-Katz	353	237	67.14	61.9-72.0
2011	Yami et al ⁵⁸	Oromia	School based	Above 8	FECT	855	388	45.4	42.0-48.8
2012	Nguyen et al ¹⁶	Amhara	School based	6-18	FECT	664	26	3.90	2.6-5.6
2013	Abera et al ¹⁹	Amhara	School based	7-14	Kato-Katz and FECT	778	361	46.4	42.9-49.9
2013	Alamir et al ¹⁸	Amhara	School based	Above 6	FECT and Wet mount	399	179	44.8	40.1-49.8
2013	Amare et al ²⁰	Amhara	School based	7-14	Kato-Katz and FECT	405	68	16.8	13.5-20.7
2013	Debalke et al ⁵⁹	Oromia	School based	5-15	McM	366	166	45.4	40.3-50.5
2013	Endris et al ¹⁷	Amhara	School based	Above 6	Kato-Katz and FECT	354	198	55.9	50.7-61.0
2013	Essa et al ²¹	Amhara	School based	7-24	Kato-Katz	579	143	24.7	21.4-28.4
2013	Gelaw et al ²²	Amhara	School based	Above 9	FECT	304	36	11.8	8.7-16.0
2013	King et al ²³	Amhara	School based	7-15	FECT	2,338	456	19.5	18.0-21.2
2013	Mahmud et al ⁷⁵	Tigray	Scholl based	6-15	Kato-Katz and FECT	600	65	10.8	8.6-13.6
2013	Mekonnen et al ⁶⁰	Oromia	School based	5-18	McM	840	437	52	48.6-55.4
2013	Tekeste et al ²⁴	Amhara	School based	5-15	Kato-Katz	326	87	26.7	22.1-31.7

(Continued)

Table 1. (Continued)

YEAR	REFERENCES	REGION	TARGET POPULATION	AGE GROUP	DIAGNOSIS METHOD USED	STUDY PARTICIPANTS			
						TOTAL	POSITIVE	PREVALENCE %	95% CI
2014	Abera and Nibret ²⁵	Amhara	School based	6-18	FECT	385	170	44.2	39.3-49.2
2014	Abossie and Seid ⁴⁰	SNNPR	School based	5-15	FECT and Wet mount	400	255	63.8	58.9-68.3
2014	Alebie et al ²⁶	Amhara	School based	5-19	Kato-Katz and FECT	384	49	12.8	9.8-16.5
2014	Asemahagn ²⁷	Amhara	School based	7-21	FECT and Wet mount	358	125	34.9	30.2-40.0
2014	Hafu et al ⁴¹	SNNPR	School based	Above 9	FECT and Wet mount	498	71	14.3	11.5-17.6
2014	Mathewos et al ²⁸	Amhara	School based	All	Kato-Katz	261	133	50.9	44.9-57.0
2014	Samuel et al ⁶¹	Oromia	School based	5-16	Kato-Katz	298	245	82.2	77.5-86.1
2014	Taye ⁶²	Oromia	School based	5-18	Kato-Katz and FECT	669	201	30	26.7-33.6
2014	Teklemariam et al ⁷⁶	Tigray	School based	5-24	FECT	480	32	6.67	4.8-9.3
2014	Tulu et al ⁶³	Oromia	School based	6-15	FECT and Wet mount	340	27	8.0	5.5-11.3
2014	Wale et al ²⁹	Amhara	School based	6-19	FECT and Wet mount	402	181	45	40.2-49.9
2014	Worku et al ³⁰	Amhara	School based	6-15	Kato-Katz and FECT	385	208	54	49.0-58.9
2015	Alelign et al ³¹	Amhara	School based	5-14	Kato-Katz	384	205	53.4	48.4-58.3
2015	Alemayehu and Tomass ⁴²	SNNPR	School based	5-14	Kato-Katz	374	224	59.9	54.9-64.7
2015	Bugssa et al ⁴³	SNNPR	School based	>6	FECT and Wet mount.	523	277	53	48.7-57.2
2015	Emana et al ⁶⁴	Oromia	School based	5-18	Kato-Katz	302	126	41.7	36.3-47.4
2015	Getnet and Worku ³³	Amhara	School based	7-18	Kato-Katz	360	91	25.3	21.1-30.0
2015	Seid et al ⁷⁷	Tigray	School based	6-20	Kato-Katz	442	29	6.56	4.4-9.3
2015	Tefera et al ⁶⁵	Oromia	School based	5-14	Mcm	715	326	45.6	42-49.3
2015	Yimer et al ³²	Amhara	School based	5-20	Kato-Katz	422	76	18	14.6-22.0
2016	Zerdo et al ⁴⁴	SNNPR	School based	5-14	Kato-Katz	408	161	39.4	34.8-44.3
2017	Aduagna et al ⁶⁶	Oromia	School based	5-18	Kat-Katz, MP and McM	381	286	75	70.5-79.2
2017	Alemayehu et al ⁴⁵	SNNPR	School based	5-19	Kato-Katz and FECT	503	189	37.6	33.5-41.9
2017	Belachew et al ⁴⁶	SNNPR	School based	Above 5	FECT and Wet mount	380	69	18.2	14.6-22.4
2017	Getachew and Argaw ⁴⁷	SNNPR	School based	7-14	FECT and Wet mount	511	238	46.6	42.3-50.9

(Continued)

Table 1. (Continued)

YEAR	REFERENCES	REGION	TARGET POPULATION	AGE GROUP	DIAGNOSIS METHOD USED	STUDY PARTICIPANTS			PREVALENCE %	95% CI
						TOTAL	POSITIVE	POSITIVE		
2017	Haile et al ⁴⁸	SNNPR	School based	5-15	FECT	463	58	12.5	9.8-15.9	
2017	Hailegebriel ³⁴	Amhara	School based	7-14	FECT.	359	144	40.1	35.2-45.3	
2017	Maru ⁷⁸	Tigray	School based	Above 5	FECT	309	125	40.5	35.1-46.0	
2017	Oswald et al ⁸⁵	Amhara	School based	6-15	FECT	11,009	2,422	22	21.2-22.8	
2017	Samuel et al ⁶⁷	Oromia	School based	6-15	FECT	317	40	12.6	9.4-16.7	
2017	Tadege and Shimelis ⁴⁹	SNNPR	School based	5-15	FECT	374	191	51	46.0-56.1	
2017	Tefera et al ⁶⁸	Oromia	School based	Above 5	McM	715	326	45.6	42.0-49.3	
2018	Gebreslassie et al ⁸⁰	Tigray	School based	5-20	FECT and Wet mount	404	49	12.13	9.1-15.7	
2018	Hailegebriel ³⁶	Amhara	School based	6 -13	FECT	382	115	30.1	25.7-34.9	
2018	Teshale et al ⁷⁹	Tigray	School based	6-19	Kato-Katz	410	26	6.3	4.4-10.1	
2019	Alemu et al ³⁷	Amhara	School based	11.5 ± 2.31	FECT	273	39	14.29	10.4-19.0	
2019	Dessie et al ⁸¹	Tigray	School based	5-14	FECT	422	19	4.50	2.7-6.9	
2019	Eyamo et al ⁵³	SNNPR	School based	Above 6	FECT	384	163	42.45	37.5-47.6	
2016	Weidengus ⁸²	Benshangul	School based	5-14	FECT and Wet mount	395	45	11.39	8.4-14.9	
2019	Alemu et al ⁵⁰	SNNPR	School based	5-14	FECT and Wet mount	351	74	21.08	16.9-25.7	
2019	Shumbej and Girum ⁵⁴	SNNPR	School based	7-25	Kato-Katz	597	47	7.87	5.8-10.3	
2019	Sisay and Lemma ⁷⁰	Oromia	School based	5-19	FECT and Wet mount	384	39	10.16	7.3-13.6	
2019	Waldesenbet et al ⁵²	SNNPR	School based	Above 6	Kato-Katz	600	57	9.50	7.3-12.1	
2019	Yarinbab and Darcha ⁵¹	SNNPR	School based	5-14	FECT	303	116	38.28	32.8-44.0	
2019	Mekonnen et al ⁶⁹	Oromia	School based	5-18	McM	1680	824	49.05	46.6-51.47	

Abbreviations: FECT, formol-ether concentration; MP, mini parasep; McM, McMaster egg count; SNNPR, south nations and nationalities peoples region.

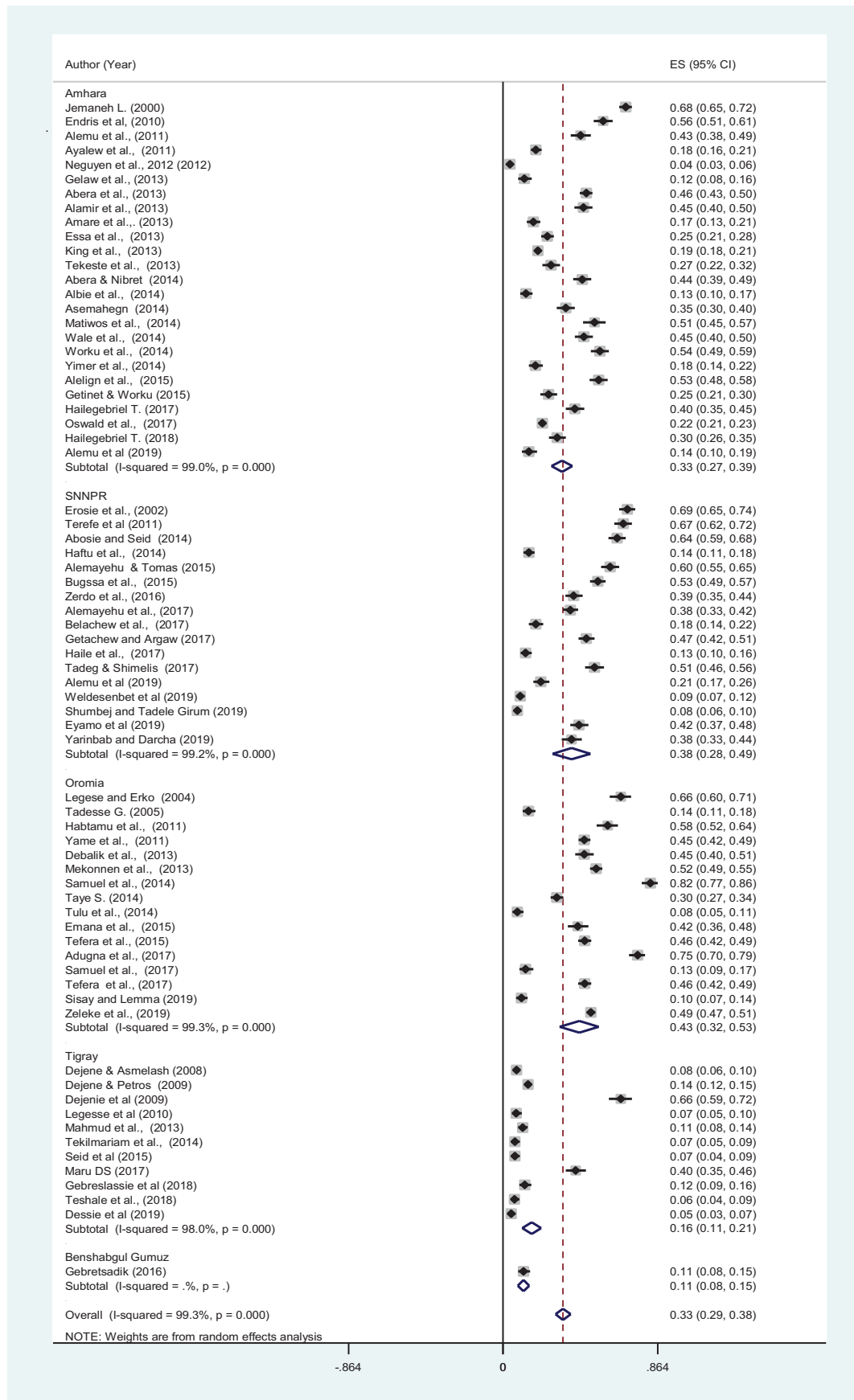


Figure 2. Forest plot for prevalence of STH among schoolchildren in Ethiopia. Each square represent effect size (ES) of individual studies and the horizontal line represent the 95% CI. The diamond indicates the pooled effect and the vertical dash lines indicate the overall estimate.

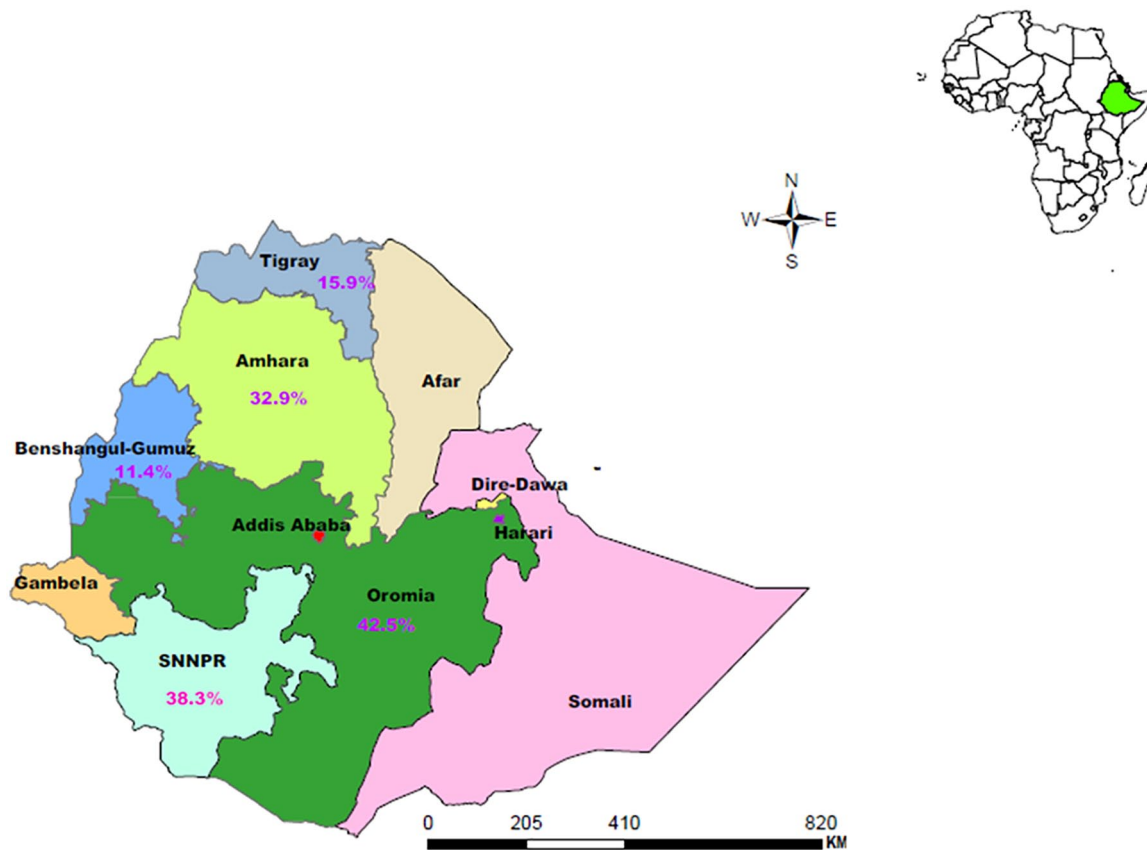


Figure 3. Regional distribution of STH among schoolchildren in Ethiopia.

The pooled prevalence of STH among SAC in years 2000 to 2010, 2011 to 2014, and 2015 to 2019 were 40.76% (95% CI 24.5%–57.1%), 34.4% (95% CI 27.2%–41.6%), and 30.6% (95% CI 25.0%–36.3%), respectively (Supplemental Figure S4). This finding has suggested the declining trends in the prevalence of STH in Ethiopia. In addition, Ethiopia launched national MDA program to reduce STH related morbidity in 2015. In order to see the contribution of MDA, we compare the pooled prevalence of STH before and after the launching of the intervention program. The result indicated that the pooled prevalence of STH declined from 35.9% to 30.6% after the launching national MDA programs in Ethiopia (Figure 4). This intervention program contributes for the reduction in the prevalence of STH in all regional states of Ethiopia. The pooled prevalence of STH was declined from 53.6% to 33.6%, 44.5% to 40%, 33.6% to 30.7%, and 17.9% to 13.6% in SNNPR, Oromia, Amhara, and Tigray regions, respectively. The highest reduction was observed from SNNPR as compared with other regional states in Ethiopia. The launching of MDA program showed encouraging results in the reduction of STH at least among schoolchildren in Ethiopia.

Six parasitological methods individually or in combination were used in the eligible articles included in this meta-analysis. The pooled prevalence of STH were 47.8% (95% CI, 45.3%–50.37%), 37.3% (95% CI, 27.1%–47.6%), 33.6% (95% CI, 21.6%–45.7%), 28.6% (95% CI, 19.6%–37.6%), 26.4% (95%

CI, 20.4%–32.3%) using McMasters, Kato-Katz, Kato-Katz and FECT, FECT and wet mount, and FECT, respectively (Supplemental Figure S6). The prevalence of STH were 75.1% (95% CI, 70.6%–79.5%) and 58.3% (95% CI, 52.3%–64.3%) using a combinations of Kato-Katz, McMaster and Mini Parasep, and Kato-Katz and FLOTAC, respectively (Supplemental Figure S6). The combinations of these techniques were used only in 2 separate studies.

Risk of publication bias across studies included in the meta-analysis

The funnel plot symmetry demonstrates the presence of publication bias among studies included in this meta-analysis (Figure 5). Similarly, the Egger's test results ($P < .05$) indicate publication bias among studies.

Meta-regression and sensitivity analysis

We performed meta-regression analysis to identify the sources of heterogeneity across studies. The meta-regression analysis showed that region of study (regression coefficient: 0.809, 95% CI, 0.689–0.950, $P = .011$) might be the source of heterogeneity (Figure 6a). Years of publication (regression coefficient: 0.908, 95% CI, 0.689–1.195, $P = 0.487$, Figure 6b) and parasitological methods used (regression coefficient: 1.094, 95% CI, 0.969–1.235, $P = 0.142$, Figure 6c) did not contribute for the

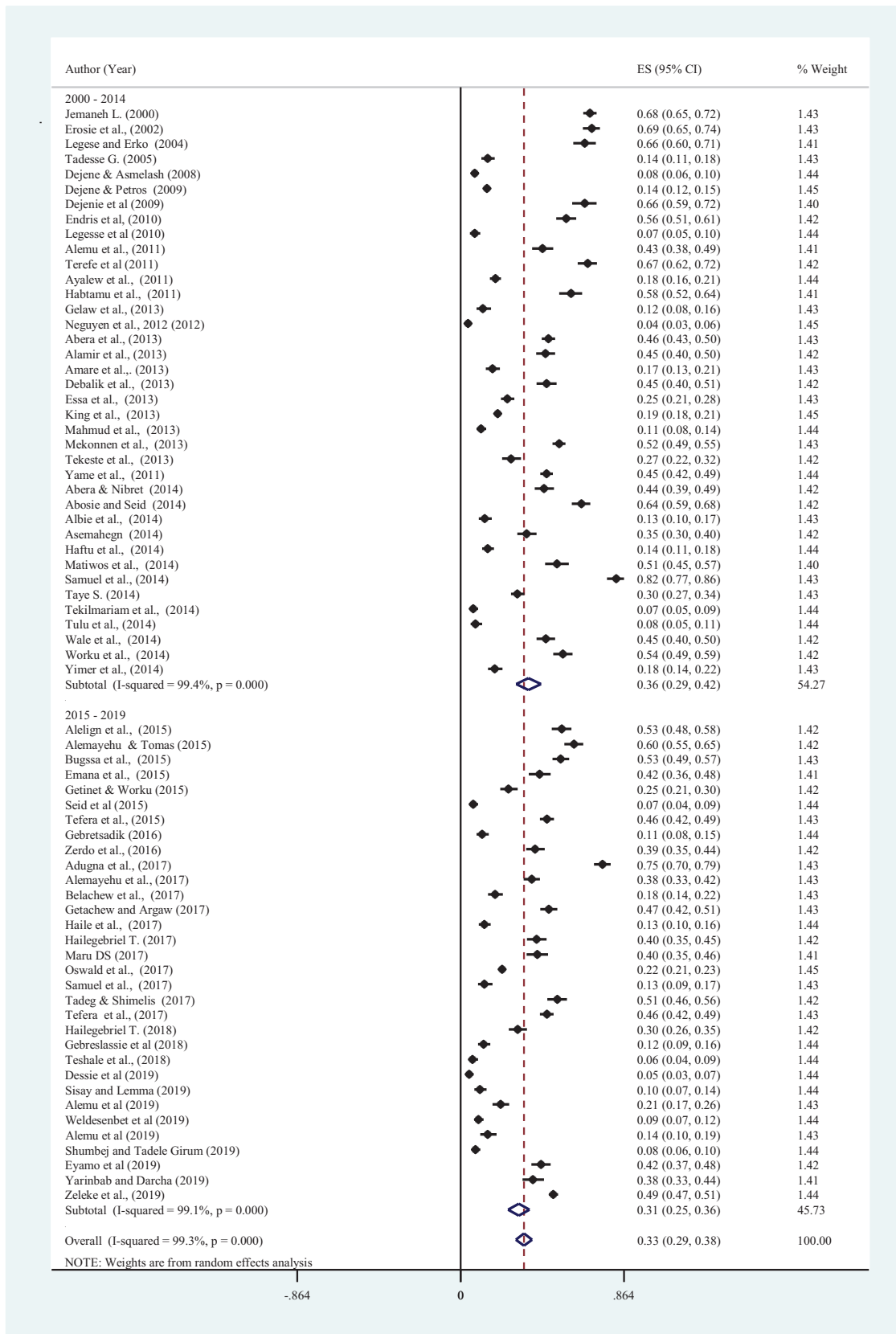


Figure 4. Forest plot showing the pooled prevalence of STH among schoolchildren in Ethiopia before and after the launching of MDA in Ethiopia.

heterogeneity. In addition, sensitivity analysis was performed by recalculating the pooled prevalence of STH by sequentially removing one-by-one to assess the contribution of individual

study the overall effect. The pooled prevalence remained stable and the result was not driven by individual studies included in the meta-analysis.

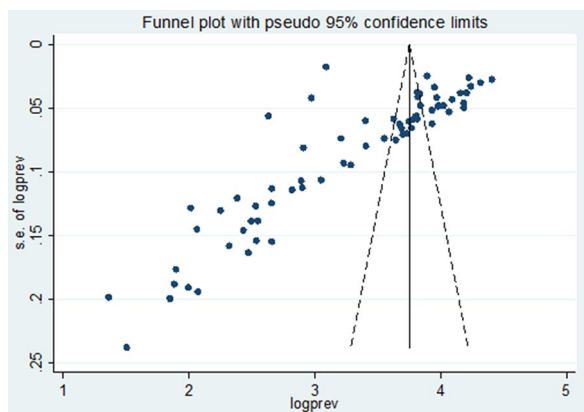


Figure 5. Funnel plot indicates publication bias across studies used in this meta-analysis.

Discussion

Soil-transmitted helminths are a group of NTDs that affects nearly a quarter of the world population.¹ To our knowledge, this is the first systematic review and meta-analysis on the prevalence of STH among SAC in Ethiopia. This review analyzed epidemiological studies on STH to estimate the pooled prevalence and to identify high-risk regions for interventions. In turn, we hope that our results will help policy-makers and other stakeholders to design appropriate control strategies for STH in Ethiopia.

The overall pooled prevalence estimates (33.4%) obtained in this review is similar to Turkey,⁸³ Kenya,⁸⁴ Nigeria,⁸⁵ and Rwanda.⁸⁶ The finding of this review is higher reports from sub-Saharan Africa^{87,88} and lower than STH reported from Afghanistan,⁸⁹ Kenya,⁹⁰ Nepal,⁹¹ and Nigeria.⁹² These differences might be associated with the presence of poor environmental sanitation and suitable climatic conditions in Ethiopia. Both the toilet coverage and level of sanitation in Ethiopia are one of the lowest in sub-Saharan Africa; about 52% of the Ethiopian population are still using unimproved sanitation facilities and 35% of them practice open defecation.⁹³ The pooled prevalence estimate of STH in this meta-analysis was even higher than that reported in a community-based study in Ethiopia.⁸⁷ Community-based studies are usually targeting both children and adult population. The exposure of adults for STH is lower than that of SAC due to better shoe wearing habits, avoidance of fecal contaminated soils and reduced soil contact. This indicates that a higher prevalence of STH is expected among SAC than in the general population. A similar observation was reported in a meta-analysis from South Asia and Southeast Asia.⁹⁴ All these data showed that SAC are vulnerable to STH than the general population in the country.

The study revealed that *A. lumbricoides* was the most prevalent STH followed by *T. trichiura* and hookworm which is in line with the global trend as well as meta-analysis reported from Nigeria,⁹² South America,⁹⁵ and Southeast Asia.⁹⁴ The higher prevalence of *A. lumbricoides* is usually associated with the suitability of the environmental condition along with the

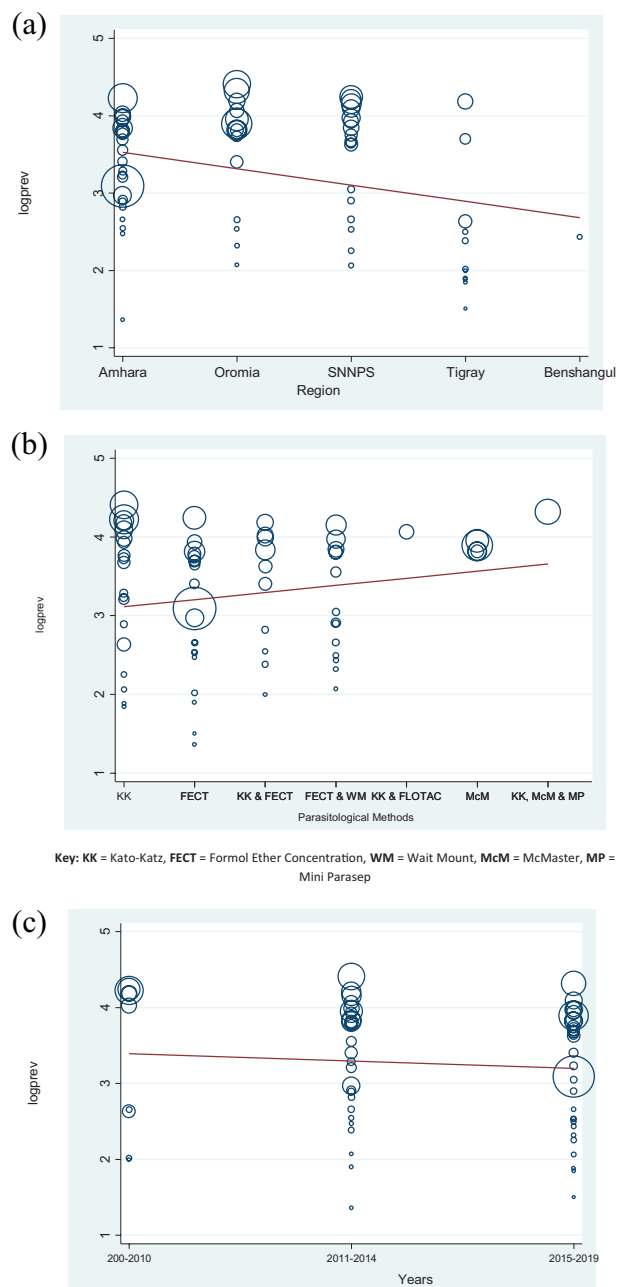


Figure 6. Meta-regression analysis of (a) Region of study. (b) Parasitological methods used. (c) Year of publication of STH among schoolchildren in Ethiopia. Abbreviations: FECT, formol ether concentration; KK, Kato-Katz; McM, McMaster; MP, mini parasep; WM, wait mount.

high fecundity of *Ascaris* and the durability of their eggs in contaminated soil. It is known that adult *A. lumbricoides* produce up to 200 000 eggs per day.⁹⁶ The pooled prevalence estimate of hookworm in the present study is lower than reports from elsewhere.^{87,92,95,97} These variations might be explained by geographical difference, socio-economic characteristics of the study populations, level of environmental sanitation, shoe wearing habits, diagnostic methods used in the different studies. The study populations included in this review were school children, which might have better shoe wearing habit that reduce the level of hookworm infections.

There are clear differences in the pooled prevalence of STH among regions in Ethiopia. The highest pooled prevalence of STH was observed from Oromia region while low pooled prevalence was observed from Tigray region. This might be associated with environmental and climatic factors (temperature, rainfall, and humidity) that contribute to the high prevalence of STH in SNNP and Oromia regions. The south and southwestern part of Ethiopia, where SNNP and the Oromia regions are located, received high rainfall and forested nature⁹⁸ as compared with the northern part of Ethiopia, which consists of Tigray and Amhara regions.

The pooled prevalence of *A. lumbricoides*, *T. trichiura* and hookworm were varied from region to region in Ethiopia. The highest pooled prevalence of *A. lumbricoides* was observed from SNNPR regional state while *T. trichiura* and hookworm were more prevalent in Oromia region. The pooled prevalence of *A. lumbricoides*, *T. trichiura* and hookworm were very low as compared with other regional states. Climatic factors of Oromia and SNNPR may create favorable conditions for the high prevalence of STH in these regions.

Several parasitological methods were used among studies used in this review. McMaster egg counting technique showed the highest pooled prevalence of STH followed by Kato-Katz fecal smear and combination of Kato-Katz and FECT. Kato-Katz thick fecal smear is the recommended parasitological methods for the detection of STH.^{9,99} Several study showed that Kato-Katz is more superior to McMaster for the detection of STH.^{100,101} However, this review indicated that McMaster was superior to Kato-Katz. These might be associated with high infection intensity of STH in the areas; all studies reporting STH using McMaster egg count was from Jimma Zone and relatively higher infection of hookworm infection in the area. Combinations of Kato-Katz, McMaster and Mini Parasep or Kato-Katz and FLOTAC resulted in higher prevalence of STH than all other methods. However, only 2 separate studies used these methods for the detection of STH in the country. A single FLOTAC is more sensitive than double or triple Kato-Katz for the diagnosis of STH.^{102,103} Combinations of the 2 or more methods generally give higher sensitivity than a single method.¹⁰⁰

This meta-analysis showed that there is a slight reduction in the prevalence of STH among SAC in recent years in the country. The highest pooled prevalence was observed before 2010 while lower prevalence was observed from 2015 onwards. The meta-regression analysis showed no significant difference in the pooled prevalence of STH in the specified years. The pooled prevalence of STH was slightly reduced from 35.9% to 30.6% after the launching of national MDA program. This result showed that MDA bring a reduction on the prevalence of STH in the country. This suggests that MDA should be implemented in all school-aged children in all parts of Ethiopia. Moreover, additional measures such as proper environmental sanitation, increased community

awareness and provisions of pure drinking water should be properly integrated into the ongoing MDA program. The pooled prevalence of STH before the launching of MDA program obtained in this review will be serves as baseline information for evaluating the outcome of MDA and other epidemiological studies in Ethiopia.

This systematic review and meta-analysis revealed that STH infections are still highly prevalent among SAC in Ethiopia. More-than one-third of SAC in Ethiopia are still positive for STH. We hope that the results of this meta-analysis will serve as an important input for policy-makers and regional administration on the control and prevention of STH in the country. This result highlights the importance of strong commitments and integrated work among stakeholders to improve environmental sanitation, increased public awareness and expand ongoing mass drug administration in Ethiopia. Combinations of these strategies might be effective in reducing the burden of STH infections from SAC in Ethiopia.

Although this systematic review generated valuable data on the prevalence of STH in Ethiopia, it has several limitations. First, the data used in this review were not derived from all regions in the country; the articles included in this meta-analysis were obtained from 5 regions (accounts for about 86% of the total population of the country) out of the 9 regional states of Ethiopia. The pooled prevalence of STH in this study may not fully represent the prevalence of STH in Ethiopia. Second, the publications on STH were not evenly distributed even in the 5 regions included in this review. Nearly 36% of the articles included in this study were reported from Amhara region while only 1.4% from Benshangul Gumuz region. Third, most of the eligible studies used single stool examination rather than multiple stool examination as recommended by WHO may results underestimation of the prevalence of STH in the country. In addition, only 44.3% of the studies included in this meta-analysis were used the recommended Kato-Katz that may leads to underestimate the true prevalence. Fourth, this review showed that there was high heterogeneity across studies included in this meta-analysis. These might be associated with study design, sources of the study population and regional variation on the prevalence of STH.


Conclusion

The present study revealed that more than one-third of SAC in Ethiopia are infected with STH. The prevalence of *A. lumbricoides*, *T. trichiura*, and hookworm among SAC follows the global trend where *A. lumbricoides* is the most prevalent followed by *T. trichiura* and hookworm. The prevalence of STH shows a slightly declined after the launching of MDA in the country. Regional variation is the major contributing factor to the heterogeneity across studies observed in the country. This review highlights the importance of an improved control and prevention strategies of STH in Ethiopia.

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Availability of supporting data

All available data are attached with the manuscript.

Supplemental material

Supplemental material for this article is available online.

REFERENCES

- WHO. Soil-transmitted helminth infections. WHO, 2020. <https://www.who.int/newsroom/fact-sheets/detail/soil-transmitted-helminth-infections>. Accessed March, 2020.
- Parija SC, Chidambaram M, Mandal J. Epidemiology and clinical features of soil-transmitted helminths. *Trop Parasitol*. 2017;7:81-85.
- WHO. *Preventive Chemotherapy In Human Helminthiasis*. Geneva, Switzerland: World Health Organization; 2006.
- Brooker S, Clements ACA, Bundy DAP. Global epidemiology, ecology and control of soil-transmitted helminth infections. *Adv Parasit*. 2006;62:221-261.
- Mara D, Lane J, Scott B, Trouba D. Sanitation and Health. *PLoS Med*. 2010;7:e1000363.
- Pabalan N, Singian E, Tabangay L, Jarjanazi H, Boivin MJ, Ezeamama AE. Soil-transmitted helminth infection, loss of education and cognitive impairment in school-aged children: a systematic review and meta-analysis. *PLoS Negl Trop Dis*. 2018;12:e0005523.
- Negussu N, Mengistu B, Kebede B, et al. Ethiopia Schistosomiasis and soil-transmitted helminthes control programme: progress and prospects. *Ethiop Med J*. 2017;55(suppl 1):75-80.
- Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*. 2009;339:b2535.
- WHO. Benchmarks for the diagnosis of intestinal parasites. *Geneva:WorldHealthOrganization*, 1994. February, 2020. <http://www.who.int/iris/handle/10665/37323>
- Hoy D, Brooks P, Woolf A, et al. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. *J Clin Epidemiol*. 2012;65:934-939.
- Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ*. 2003; 327:557-560.
- Melsen WG, Bootsma MCJ, Rovers MM, Bonten MJM. The effects of clinical and statistical heterogeneity on the predictive values of results from meta-analyses. *Clin Microbiol Infect*. 2014;20:123-129.
- Jemaneh L. The epidemiology of *Schistosomiasis mansoni* and soil-transmitted helminths in elementary school children from the South Gondar Zone of the Amhara National Regional State, Ethiopia. *Ethiop Med J*. 2000;38:105-118.
- Alemu A, Atnafu A, Addis Z, et al. Soil-transmitted helminths and *Schistosoma mansoni* infections among school children in zarima town, northwest Ethiopia. *BMC Infect Dis*. 2011;11:189.
- Ayalew A, Debebe T, Worku A. Prevalence and risk factors of intestinal parasites among Delgi school children, North Gondar, Ethiopia. *J Parasitol Vector Biol* 2011;3:75-81.
- Nguyen NL, Gelaye B, Aboset N, Kumie A, Williams MA, Berhane Y. Intestinal parasitic infection and nutritional status among school children in Angolela, Ethiopia. *J Prev Med Hyg*. 2012;53:157-164.
- Endris M, Tekeste Z, Lemma W, Kassu A. Comparison of the Kato-Katz, Wet Mount, and Formol-Ether concentration diagnostic techniques for intestinal helminth infections in Ethiopia. *ISRN Parasitol*. 2013;2013:180439.
- Alamir M, Awoke W, Feleke A. Intestinal parasites infection and associated factors among school children in Dagi primary school, Amhara National Regional State, Ethiopia. *Health*. 2013;5:1697-701.
- Abera B, Alem G, Yimer M, Herrador Z. Epidemiology of soil-transmitted helminths, *Schistosoma mansoni*, and haematocrit values among schoolchildren in Ethiopia. *J Infect Dev Ctries*. 2013;7:253-260.
- Amare B, Ali J, Moges B, et al. Nutritional status, intestinal parasite infection and allergy among school children in Northwest Ethiopia. *BMC Pediatrics*. 2013;13:7.
- Essa T, Birhane Y, Endris M, Moges A, Moges F. Current status of *Schistosoma mansoni* infections and associated risk factors among students in Gorgora Town, Northwest Ethiopia. *ISRN Infect Dis*. 2013;2013:7.
- Gelaw A, Anagaw B, Nigusie B, et al. Prevalence of intestinal parasitic infections and risk factors among schoolchildren at the University of Gondar Community School, Northwest Ethiopia: a cross-sectional study. *BMC Pub Health*. 2013;13:304.
- King JD, Endeshaw T, Escher E, et al. Intestinal parasite prevalence in an area of Ethiopia after implementing the SAFE Strategy, Enhanced Outreach Services, and Health Extension Program. *PLoS Negl Trop Dis*. 2013;7:e22223.
- Tekeste Z, Belyhun Y, Gebrehiwot A, et al. Epidemiology of intestinal schistosomiasis and soil-transmitted helminthiasis among primary school children in Gorgora, Northwest Ethiopia. *Asian Pac J Trop Dis*. 2013;3:61-64.
- Abera A, Nibret E. Prevalence of gastrointestinal helminthic infections and associated risk factors among schoolchildren in Tilili town, northwest Ethiopia. *Asian Pac J Trop Med*. 2014;7:525-530.
- Alebie G, Erko B, Aemero M, Petros B. Epidemiological study on *Schistosoma mansoni* infection in Sanja area, Amhara region, Ethiopia. *Parasit Vectors*. 2014;7:15.
- Asemahagn MA. Parasitic infection and associated factors among the primary school children in Motta Town, Western Amhara, Ethiopia. *Am J Public Health Res*. 2014;2:248-254.
- Mathewos B, Alemu A, Woldeyohannes D, et al. Current status of soil-transmitted helminths and *Schistosoma mansoni* infection among children in two primary schools in North Gondar, Northwest Ethiopia: a cross sectional study. *BMC Res Notes*. 2014;7:88.
- Wale M, Wale M, Fekensa T. The prevalence of intestinal helminthic infections and associated risk factors among school Children in Lumame town, Northwest, Ethiopia. *J Parasitol Vector Biol*. 2014;6:156-165.
- Worku L, Damte D, Endris M, Tesfa H. Aemero Mulugeta. *Schistosoma mansoni* Infection and Associated Determinant Factors among School Children in Sanja Town, Northwest Ethiopia. *J Parasitol Res*. 2014;2014:792536.
- Alelign T, Degarege A, Erko B. Soil-transmitted helminth infections and associated risk factors among school children in Durbete Town, Northwestern Ethiopia. *J Parasitol Res*. 2015;2015:641602.
- Yimer M, Hailu T, Mulu W, Abera B. Evaluation performance of diagnostic methods of intestinal parasitosis in school age children in Ethiopia. *BMC Res Notes*. 2015;8:820.
- Getnet A, Worku S. The association between major helminth infections (soil-transmitted helminthes and Schistosomiasis) and anemia among school children in Shimbit elementary school, Bahir Dar, Northwest Ethiopia. *Am J Health Res*. 2015;3:97-104.
- Hailegebriel T. Prevalence of intestinal parasitic infections and associated risk factors among students at Dona Berber primary school, Bahir Dar, Ethiopia. *BMC Infect Dis*. 2017;17:362.
- Oswald WE, Stewart AEP, Kramer MR, et al. Association of community sanitation usage with soil-transmitted helminth infections among school-aged children in Amhara Region, Ethiopia. *Parasit Vectors*. 2017;10:91.
- Hailegebriel T. Undernutrition, intestinal parasitic infection and associated risk factors among selected primary school children in Bahir Dar, Ethiopia. *BMC Infect Dis*. 2018;18:394.
- Alemu M, Anley A, Tedla K. Magnitude of intestinal parasitosis and associated factors in rural school children, Northwest Ethiopia. *Ethiop J Health Sci*. 2019;29:923-928.
- Erosie L, Merid Y, Ashiko A, et al. Prevalence of hookworm infection and haemoglobin status among rural elementary school children in Southern Ethiopia. *Ethiop J Health Dev*. 2002;16:113-115.
- Terefe A, Shimelis T, Mengistu M, Hailu A, Erko B. *Schistosomiasis mansoni* and soil-transmitted helminthiasis in Bushulo village, southern Ethiopia. *Ethiop J Health Dev*. 2011;25:46-50.
- Abossie A, Seid M. Assessment of the prevalence of intestinal parasitosis and associated risk factors among primary school children in Chencha town, Southern Ethiopia. *BMC Pub Health*. 2014;14:166.
- Haftu D, Deyessa N, Agedew E. Prevalence and determinant factors of intestinal parasites among school children in Arba Minch town, Southern Ethiopia. *Am J Health Res*. 2014;2:247-254.
- Alemayehu B, Tomass Z. Prevalence of intestinal helminthiasis and associated risk factors among school children in Dawro Zone, Southern Ethiopia. *J Biol Agri Healthcare* 2015;5:76-82.
- Bugssa G, Dessalegn B, Alemu M, Desta H, Kahsay T. A survey of intestinal parasitic infections among Dega Ochollo primary school children, Ochollo, South Ethiopia. *Sci J Publ Health*. 2015;3:56-60.
- Zerdo Z, Yohanes T, Tariku B. Soil-transmitted helminth reinfection and associated risk factors among school-age children in Chencha District, Southern Ethiopia: a cross-sectional study. *J Parasitol Res*. 2016;2016:1-7.
- Alemayehu B, Tomass Z, Wadilo F, Leja D, Liang S, Erko B. Epidemiology of intestinal helminthiasis among school children with emphasis on *Schistosoma*

- mansoni* infection in Wolaita zone, Southern Ethiopia. *BMC Pub Health*. 2017;17:587.
46. Belachew EB, Tarko DB, Wallie YM. Prevalence of intestinal helminthic parasitic infections and associated risk factors among students in Tepi Town, South West Ethiopia. *Sci J Publ Health*. 2017;5:192-197.
 47. Getachew T, Argaw A. Intestinal helminth infections and dietary diversity score predict nutritional status of urban schoolchildren from southern Ethiopia. *BMC Nutrition* 2017;3:9.
 48. Haile A, Abera T, Dana D. The prevalence of intestinal parasitic infection and associated factors among primary school children in Gurage Zone, South Ethiopia. *JPAM*. 2017;15:8-14.
 49. Tadege B, Shimelis T. Infections with *Schistosoma mansoni* and geohelminths among school children dwelling along the shore of the Lake Hawassa, Southern Ethiopia. *PLoS One*. 2017;12:e0181547.
 50. Alemu G, Abossie A, Yohannes Z. Current status of intestinal parasitic infections and associated factors among primary school children in Birbir town, Southern Ethiopia. *BMC Infect Dis*. 2019;19:270.
 51. Yarinbab TE, Darcha AD. Prevalence and determinants of soil transmitted helminthes infections among primary school children in Kerewo Town, Gena Bossa Woreda, Ethiopia: cross sectional study. *J Infect Dis Epidemiol* 2019;5:90.
 52. Weldesenbet H, Worku A, Shumbej T. Prevalence, infection intensity and associated factors of soil transmitted helminths among primary school children in Gurage zone, South Central Ethiopia: a cross-sectional study design. *BMC Res Notes*. 2019;12:231.
 53. Eyamo T, Girma M, Alemayehu T, Bedewi Z. Soil-transmitted helminths and other intestinal parasites among schoolchildren in Southern Ethiopia. *Res Rep Trop Med*. 2019;10:137-143.
 54. Shumbej T, Girum T. Helminth infections in light of an ongoing intervention in endemic areas of Gurage zone, Southern Ethiopia: an implication for neglected tropical diseases elimination in Ethiopia by 2020. *Trop Dis Travel Med Vaccines*. 2019;5:8.
 55. Legesse M, Erko B. Prevalence of intestinal parasites among school children in rural area close to the south east of lake Langano, Ethiopia. *Ethiop J Health Dev* 2004;18:116-120.
 56. Tadesse G. The prevalence of intestinal helminthic infections and associated risk factors among school children in Babile town, Eastern Ethiopia. *Ethiop J Health Dev*. 2005;19:140-147.
 57. Habtamu K, Degarege A, Ye-Ebiyo Y, Erko B. Comparison of the Kato-Katz and FLOTAC techniques for the diagnosis of soil-transmitted helminth infections. *Parasitol Int*. 2011;60:398-402.
 58. Yami A, Mamo Y, Kebede S. Prevalence and predictions of intestinal helminthiasis among school children in Jimma Zone; a cross-sectional study. *Ethiop J Health Sci*. 2011;21:167-174.
 59. Debalke S, Worku A, Jahur N, Mekonnen Z. Soil-transmitted helminths and associated factors among schoolchildren in government and private primary school in Jimma Town, Southwest Ethiopia. *Ethiop J Health Sci*. 2013;23:237-244.
 60. Mekonnen Z, Meka S, Ayana M, Bogers J, Vercruyse J, Levecke B. Comparison of individual and pooled stool samples for the assessment of soil-transmitted helminth infection intensity and drug efficacy. *PLoS Negl Trop Dis*. 2013;7:e2189.
 61. Samuel F, Degarege A, Erko B. Efficacy and side effects of albendazole currently in use against *Ascaris*, *Trichuris* and hookworm among school children in Wondo Genet, Southern Ethiopia. *Parasitol Int*. 2014;63:450-455.
 62. Taye S. Comparison of Kato-Katz and Formol-Ether concentration methods for the diagnosis of intestinal helminthic infections among school children of Wonji Shoa town, Eastern Ethiopia: a school based cross-sectional study. *Am J Health Res* 2014;2:271-274.
 63. Tulu B, Taye S, Amsalu E. Prevalence and its associated risk factors of intestinal parasitic infections among Yadot primary school children of South Eastern Ethiopia: a cross-sectional study. *BMC Res Notes*. 2014;7:848.
 64. Emanu D, Jemal K, Bajiro M, Mekonnen Z. Prevalence and intensity of soil-transmitted helminths among school-aged children in Sigo primary school, Jimma Zone, South-Western Ethiopia. *J Clin Med Res*. 2015;4:98-103.
 65. Tefera E, Belay T, Mekonnen S, Zeynudin A, Belachew T. Therapeutic efficacy of different brands of albendazole against soil-transmitted helminths among students of Mendera Elementary School, Jimma, Southwest Ethiopia. *Pan Afr Med J*. 2015;22:252.
 66. Adugna S, Kebede T, Mekonnen Z, Degarege A, Liange S, Erko B. Diagnostic performance of Mini Parasep® solvent-free faecal parasite concentrator relative to Kato-Katz and McMaster for the diagnosis of intestinal parasitic infections. *Trans R Soc Trop Med Hyg*. 2017;111:572-578.
 67. Samuel F, Demsew A, Alem Y, Hailesilassie Y. Soil-transmitted helminthiasis and associated risk factors among elementary school children in ambo town, Western Ethiopia. *BMC Publ Health*. 2017;17:791.
 68. Tefera E, Belay T, Mekonnen SK, Zeynudin A, Belachew T. Prevalence and intensity of soil-transmitted helminths among school children of Mendera Elementary School, Jimma, Southwest Ethiopia. *Pan Afr Med J*. 2017;27:88.
 69. Mekonnen Z, Getachew M, Bogers J, Vercruyse J, Levecke B. Assessment of seasonality in soil-transmitted helminth infections across 14 schools in Jimma Town, Ethiopia. *Pan Afr Med J*. 2019;32:6.
 70. Sisay A, Lemma B. Assessment on the prevalence and risk factors of gastrointestinal parasites on schoolchildren at Bochesa Elementary School, around Lake Zwai, Ethiopia. *BMC Res Notes*. 2019;12:410.
 71. Dejene T, Asmelash T. Impact of irrigation on the prevalence of intestinal parasites infection with emphasis on Schistosomiasis in Hintallo-Wejerat, North Ethiopia. *Ethiop J Health Sci*. 2008;18:33-38.
 72. Dejenie T, Asmelash T, Teferi M. Intestinal helminthes infections and re-infections with special emphasis on *Schistosoma mansoni* in Waja, North Ethiopia. *MEJS*. 2009;1:4-16.
 73. Dejenie T, Petros P. Irrigation practices and intestinal helminth infections in southern and central Zones of Tigray. *Ethiop J Health Dev*. 2009;23:48-56.
 74. Legesse L, Erko B, Hailu A. Current status of intestinal Schistosomiasis and soil-transmitted helminthiasis among primary school children in Adwa Town, Northern Ethiopia. *Ethiop J Health Dev* 2010;24:191-197.
 75. Mahmud MA, Spigt M, Mulugeta Bezabih A, López Pavon I, Dinant G-J, Blanco Velasco R. Risk factors for intestinal parasitosis, anaemia, and malnutrition among school children in Ethiopia. *Pathog Glob Health*. 2013;107:58-65.
 76. Teklemariam A, Dejenie T, Tomass Z. Infection prevalence of intestinal helminths and associated risk factors among schoolchildren in selected kebeles of Enderta district, Tigray, Northern Ethiopia. *J Parasitol Vector Biol*. 2014;6:166-173.
 77. Seid M, Dejenie T, Tomass Z. Prevalence of Intestinal Helminths and Associated Risk Factors in Rural School-Children in Were-Abaye Sub District, Tigray Region, Northern Ethiopia. *Acta Parasitologica Globalis* 2015;6:29-35.
 78. Maru DS. Prevalence of intestinal parasitic infections and associated risk factors among school children in Adigrat town, Northern Ethiopia. *IJETTCS*. 2017;4:4943-4948.
 79. Teshale T, Belay S, Tadesse D, Awala A, Teklay G. Prevalence of intestinal helminths and associated factors among school children of Medebay Zana wereda; North Western Tigray, Ethiopia 2017. *BMC Res Notes* 2018;11:444.
 80. Gebreslassie M, Dejenie T, Tomass Z. Prevalence of intestinal parasites and associated risk factors in schoolchildren of Aksum Town, Northern Ethiopia. *Acta Parasitol Glob* 2015;6:42-48.
 81. Dessie A, Gebrehiwot TG, Kiros B, Wami SD, Chercos DH. Intestinal parasitic infections and determinant factors among school-age children in Ethiopia: a cross-sectional study. *BMC Res Notes*. 2019;12:777.
 82. Weidengus GG. Current status of intestinal parasites and associated risk factors among schoolchildren of Homesha district in northwest Ethiopia. *Int J Curr Res*. 2016;9:54369-54374.
 83. Okyay P, Ertug S, Gultekin B, Onen O, Beser E. Intestinal parasites prevalence and related factors in school children, a western city sample-Turkey. *BMC Pub Health*. 2004;4:64.
 84. Odieri MR, Opisa S, Odhiambo G, et al. Geographical distribution of schistosomiasis and soil-transmitted helminths among school children in informal settlements in Kisumu City, Western Kenya. *Parasitology*. 2011;138:1569-1577.
 85. Sowemimo OA, Asaolu SO. Current status of soil-transmitted helminthiasis among pre-school and school-aged children from Ile-Ife, Osun State, Nigeria. *J Helminthol*. 2011;85:234-238.
 86. Staudacher O, Heimer J, Steiner F, et al. Soil-transmitted helminths in southern highland Rwanda: associated factors and effectiveness of school-based preventive chemotherapy. *Trop Med Int Health*. 2014;19:812-824.
 87. Karagiannis-Voules DA, Biedermann P, Ekpo UF, et al. Spatial and temporal distribution of soil-transmitted helminth infection in sub-Saharan Africa: a systematic review and geostatistical meta-analysis. *Lancet Infect Dis*. 2015;15:74-84.
 88. Pullan RL, Smith JL, Jasrasaria R, Brooker SJ. Global numbers of infection and disease burden of soil transmitted helminth infections in 2010. *Parasit Vectors*. 2014;7:37.
 89. Gabrielli AF, Ramsan M, Naumann C, et al. Soil-transmitted helminths and haemoglobin status among Afghan children in World Food Programme assisted schools. *J Helminthol*. 2005;79:381-384.
 90. Ngonjo T, Okoyo C, Andove J, et al. Current status of soil-transmitted helminths among school children in Kakamega County, Western Kenya. *J Parasitol Res*. 2016;2016:7680124.
 91. Kunwar R, Acharya L, Karki S. Decreasing prevalence of intestinal parasitic infections among school-aged children in Nepal: a systematic review and meta-analysis. *Trans R Soc Trop Med Hyg*. 2016;110:324-332.
 92. Karshima SN. Prevalence and distribution of soil-transmitted helminth infections in Nigerian children: a systematic review and meta-analysis. *Infect Dis Poverty*. 2018;7:69.
 93. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. *BMC Pub Health*. 2015;15:451.

94. Silver ZA, Kaliappan SP, Samuel P, et al. Geographical distribution of soil-transmitted helminths and the effects of community type in South Asia and South East Asia - a systematic review. *PLoS Negl Trop Dis*. 2018;12:e0006153.
95. Chammartin F, Scholte RGC, Guimarães LH, Tanner M, Utzinger J, Vounatsou P. Soil-transmitted helminth infection in South America: a systematic review and geostatistical meta-analysis. *Lancet Infect Dis*. 2013;13:507-518.
96. Arfaa F. Selective primary health care: strategies for control of disease in the developing world. XII. Ascariasis and trichuriasis. *Rev Infect Dis*. 1984;6:364-373.
97. Wright JE, Werkman M, Dunn JC, Anderson RM. Current epidemiological evidence for predisposition to high or low intensity human helminth infection: a systematic review. *Parasites Vectors*. 2018;11:65.
98. Negash W, Goel NK, Jain MK. Temporal and spatial variability of annual and seasonal rainfall over Ethiopia. *Hydrol Sci J* 2013;58:354-373.
99. WHO. *Assessing the Efficacy of Anthelmintic Drugs against Schistosomiasis and Soil-Transmitted Helminthiases*. Geneva, Switzerland: World Health Organization; 2013.
100. Periago MV, Diniz RC, Pinto SA, et al. The right tool for the job: detection of soil-transmitted helminths in areas co-endemic for other helminths. *PLoS Negl Trop Dis*. 2015;9:e0003967.
101. Levecke B, Behnke JM, Ajjampur SSR, et al. A comparison of the sensitivity and fecal egg counts of the McMaster egg counting and Kato-Katz thick smear methods for soil-transmitted helminths. *PLoS Negl Trop Dis*. 2011;5:e1201.
102. Knopp S, Rinaldi L, Khamis IS, et al. A single FLOTAC is more sensitive than triplicate Kato-Katz for the diagnosis of low-intensity soil-transmitted helminth infections. *Trans R Soc Trop Med Hyg*. 2009;103:347-354.
103. Nikolay B, Brooker SJ, Pullan RL. Sensitivity of diagnostic tests for human soil-transmitted helminth infections: a meta-analysis in the absence of a true gold standard. *Int J Parasitol*. 2014;44:765-774.