National mapping of soil-transmitted helminth and schistosome infections in Ethiopia

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Abstract

Background: The geographical distributions of both soil-transmitted helminths (STHs; *Ascarislumbricoides*, *Trichuristrichiura*, and the hookworms (*Necatoramericanus* and *Ancylostomaduodenale*) and schistosomes (SCH; *Schistosomamansoni* and *S. haematobium*) are pivotal to be able to effectively design and implement mass drug administration (MDA) programs. The objective of this mapping was to provide up-to-date data on the distribution of both STH and SCH for Ethiopia to inform the national control program.

Methodology: Between 2013 and 2015, we assessed the distributions of STHs and SCH in a nationwide survey covering 153,238 school-aged children (aged five to 15 years), from 786woredas (districts), representing all nine Regional States and two City Administrations of Ethiopia. From these surveys, nationwide disease maps were developed which allow recommendations to be made on the implementation of MDA programs.

Principal findings: The prevalence of any STH infection across the study population was 21.7%, with *A. lumbricoides* (12.8%) the most prevalent, followed by hookworms (7.5%) and *T. trichiura* (5.9%). The prevalence for any SCH was 3.8%, with *S. mansoni* (3.5%) the dominant and *S. haematobium* was less prevalent (0.3%).STHs were more prevalent in southwest Ethiopia, whereas SCH found mostly in the west and northeast of the country. The prevalence of moderate-to-heavy intensity infections was 2% for STHs and 1.6% for SCH.

Based on the disease maps and on WHO guidance for STH, 279 woredas were classified as highly endemic and therefore qualify for treatment twice per year and 215 woredas were moderate endemic and qualify for treatment once per year. For SCH, 69 woredas were classified as highly endemic and qualify for treatment once per year and 153 woredas were moderate endemic and qualify for treatment every two years.

Conclusions/Significance: the results confirm that Ethiopia is endemic for both STHs and SCH, posing a significant public health problem. Following the WHO recommendations on mass drug administration, 18 and 14 million school-aged children are in need of MDA for STHs and SCH respectively.

Author Summary

Today, intestinal worm (giant roundworm, whipworm and hookworm) and blood-dwelling worm (schistosome) infections represent a public health problem in Ethiopia. Knowledge on the distribution of these worms is pivotal to design and implement control strategies, but up-to-date disease maps were not available for Ethiopia. We assessed the distributions of both intestinal and blood dwelling worms in school-age children. Our result confirms that Ethiopia is endemic to intestinal and blood dwelling worms. At the national level, these worms were prevalent in school-age children, but a wide geographical variation in prevalence and intensity of infections was observed. The finding from the disease maps will support the national control program's targeted delivery of large-scale deworming to the areas that are most in need, reaching 18.4 million school-age children suffering from intestinal and blood-dwelling worms.

Introduction

Neglected tropical diseases (NTDs) are a diverse group of bacterial, parasitic and viral communicable diseases. They are widespread in tropical and subtropical countries where; poverty, inadequate sanitation and hygiene are common[1]. A group of these NTDs can be controlled by either innovation or intensified disease management at the level of the individual patient, or through mass drug administration (MDA) to the most at-risk populations. Some of the MDA-amenable parasites include the soil-transmitted helminths (STHs: Ascarislumbricoides, Trichuristrichiura and the hookworms (Nectatoramericanus and Ancylostomaduodenale) and schistosomes (SCH: S. mansoni and S. haematobium). The MDA platforms for these NTDs are mainly based on deworming children at school. The recommended dosages for deworming are a single oral dose of albendazole (400 mg) or mebendazole (500 mg) for STHs, and praziquantel for SCH (40 mg/kg; this often approximated by height using a dose-pole [2]). The global community has committed to cover at least 75% of the school-age children (SAC) in endemic areas for both STHs and SCH by 2020[3]. The frequency and populations targeted for MDA are determined by the prevalence in a given geographical area. For STHs, it is recommended to distribute drugs twice a year when the prevalence of any STHs exceeds 50%, and once a year when the prevalence is at least 20%. For prevalence below 20%, a case-by-case treatment is recommended[4]. For SCH, an annual round of MDA is recommended when the prevalence is ≥ 50%, every two years when the prevalence is ≥ 10%. For any other prevalence of ≥ 1%, twice MDA during the primary school years is recommended [2].

Historical data suggest that both STHs and SCH are prevalent in Ethiopia[5–9]. In 2012, it was concluded that Ethiopia represents one of the top five sub-Saharan countries with the highest prevalence of STHs (second place for Ascaris, third place for hookworm and fourth for Trichuris). For SCH, Ethiopia has the 14th highest prevalence [10]. Across the country there is huge geographical disease distribution studies, reporting wide prevalence ranges [5, 6, 9, 11, 12]. However, these studies are not ideal for making recommendations on the best MDA strategy at a national level. At first, they are not up-to-date (early 1970th to 2015th ; [5, 9, 13], nor do they cover the entire country. Moreover, they differ considerably in sample size; number of schools, number of subjects per school, number of woredas included and the diagnostic method applied (Kato-Katz thick smear; wet mount [9, 12, 14, 15], which further complicates effectively designing and implementing MDA programs. Since 2000, the Ethiopian government has been implementing deworming of children in under five years of age against STHs, as part of an integrated vitaminA Supplementation program. For SCH, the country has focused on case-based treatment of laboratory-confirmed patients. Following the London Declaration on NTDs in 2012[16], the Federal Ministry of Health of Ethiopia (FMOH) developed an NTD Master Plan, which outlines a roadmap for combating the country's most common NTDs [17],with the ultimate goal of the control or elimination. For STHs and SCH, the target has been set to control morbidity through the reduction of moderate-to-heavy intensity infections by means of MDA. Up-to-date data on disease distribution is therefore pivotal to ensure the area's most in need of MDA are covered and to avoid the initiation of large-scale deworming in areas where disease is rare or absent[4, 18].

Here, we describe the distribution of STHs and SCH in 153,238 SAC, across 3,142 schools in 786 woredas, across all nine Regions and two City Administrations in Ethiopia. We present disease distribution maps to plan the necessary drugs and frequency of MDA that will support the national deworming program for STHs and SCH in SAC in Ethiopia.

Methods

Study area

In 2015, the Ethiopia's population was estimated at 100 million[19]. The country has three administrative levels. The first level includes nine Regional States: Afar, Amhara, Benishangul-Gumuz, Gambela, Harari, Oromiya, Southern Nations, Nationalities and Peoples' Region (SNNPR), Somali and Tigray; and two chartered City Administrations: Addis Ababa and Dire Dawa. The second and the third administrative levels are zones and woredas (districts), respectively. The woredas are the implementation units for NTD control programs in Ethiopia.

The distribution of STHs and SCH was mapped over two surveys. In the first survey (November2013 to March 2014), eight of the nine Regional States and one of the two City Administrations were included. In the second survey (February and April 2015) both Amhara and Addis Ababa were mapped. In addition, there was a fine-scale mapping survey in Somali Regional State with the aim to cover woredas that were not mapped in the first survey.

Field procedures

The field teams were provided with a list of ten schools per woreda for the regions and ten schools per sub-city for each of the two City Administrations. These ten schools were randomly selected from the list of elementary schools provided by the Federal Ministry of Education. Ultimately, only five schools were purposively selected and included in the survey. This final selection was done by the Woreda Health Office and was biased towards schools that were at-risk for SCH infections (proximity to water bodies, reports on SCH infections, irrigation and fishing practices of the community). Once the school selection was completed, the field team made the necessary pre-visit arrangements with the school directors. On the day of visit, all students of grade 5 (around 12 years of age) were lined up in two lines, one for the girls and one for the boys. A random selection was made of 25 girls and 25 boys, resulting in a total of 50 students per school. In schools with fewer than 25 boys or girls in the appropriate grade, children from lower grades (grade four: roughly 11 years of age) or higher grade (grade six: roughly 13 years of age) were included. The selected students were asked to provide both a stool and a urine sample.

Stool samples were screened for the presence of STHs and S. mansoni eggs, applying a single Kato-Katz thick smear[20].The number of eggs of STHs (A. lumbricoides, T. trichiura, and hookworms) and S. mansoni were multiplied by 24 to obtain the faecal egg counts (FECs) expressed in eggs per gram of stool (EPG) for each of the four helminth species.

Urine specimens were screened for S. haematobium in two consecutive steps. First, the presence of haematuria was assessed using Haemastix®. The results of this test were recorded as either negative, trace, +, ++ or +++. Subsequently, urine samples in which at least a trace of haematuria was detected were subjected to urine filtration to assess the number of S. haematobium eggs in 10 ml of urine.

To ensure the quality of the parasitological results the field team were instructed to randomly archive 10% of the Kato-Katz slides. These slides were re-examined by the team leader. Any discrepancies were discussed with the wider team.

In addition, a questionnaire was completed. This questionnaire was designed to gain information on water; sanitation and hygiene (WASH) at the school level. The results of this questionnaire and parasite infection for the first round of survey are reported elsewhere by Grimes and colleagues[21].

Training of the field teams

In total, 54field teams from the different Regional States and City Administrations were involved in this study. Each team consisted of one health officer (for the questionnaires and treatment) and three laboratory technicians (for the stool and urine sample examinations).Training was given for each survey. The training was provided at the Ethiopian Management Institute (EMI) in Bishoftu. During these trainings, both theoretical and practical sessions were given to 164 Health officers and laboratory technicians. The technical sessions focussed on a variety of aspects of the diseases (life cycles, pathogenesis, laboratory diagnosis, prevention and control strategies), while the practical sessions focussed on the diagnostic methods (the use of Haemastix®, urine filtration, Kato-Katz thick smear), archiving Kato-Katz slides for quality control, completing questionnaires on WASH and using LINKS® (a smart phone-based application to collect data).

Mapping coordination and supervision

Supplementary Fig. 1 provides an overview of the coordination and supervision of this study. EPHI, the technical arm of FMoH, was responsible for the overall coordination of the survey. For this coordination, four central supervisors were assigned. At the Regional States and City Administrations, at least one supervisor from either the Regional Health or Education Office for each Regional State (and City Administration) was assigned throughout the mapping period. In addition, external supervisors from the Ugandan Vector Control Division (Uganda) and the Kenyan Medical Research Institute (Kenya) conducted monitoring visits. These supervisors independently evaluated the survey coordination and communication flow between the central level (EPHI), the regional supervisors (Regional States and City Administration) and the field teams. They also monitored the operational procedures at the schools, providing feedback to the field teams, correcting those that were not adhering to the mapping protocol.

Data collection and data management

Data was collected using the LINKS® data collection system developed by the Task Force for Global Health (Atlanta, USA). This is an android-based application that allows standardized entry of epidemiological data across the different teams. At the school level, the teams collected the GPS coordinates, the total number of students, the total number of boys and girls in the school, the availability of toilets, water supplies and hand washing facilities. At the level of the student, the teams collected the age, sex, the number of Ascaris, Trichuris, hookworm, S. mansoni eggs, the presence of haematuria, and the number of S. haematobium eggs. Raw data was downloaded from the LINKS system server and was subsequently curated using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).

Statistical data analysis

The prevalence and intensity of infections were calculated for any STH and SCH, and the individual helminth species, separately. Prevalence was estimated by the proportion of children for whom eggs of a particular helminth species were detected. Unweighted prevalence was calculated at regional and woreda level, to this end the proportion of children excreting eggs over the total number screened in the region / woreda was calculated. For treatment, mean prevalence of the five schools was used to decide the eligibility of that woreda for treatment.

Intensity of infection was measured as the arithmetic mean FECs and as the proportion of low and moderate-to-heavy intensity infections. The criteria for the classification of infection intensities are summarized in Table 1. In addition, we determined the prevalence of mixed infections (the proportion of children who were excreting eggs of at least two different helminths).

Table 1
Infection intensity criteria for: A. lumbricoides, T. trichiura, hookworms, S. mansoni and S. haematobium infections.

Helminth	Light	Moderate	Heavy
A. lumbricoides	1–4 999 EPG	5 000–49 999 EPG	≥ 50 000 EPG
T. trichiura	1–999 EPG	1 000–9 999 EPG	≥ 10 000 EPG
Hookworms	1–1 999 EPG	2 000–3 999 EPG	≥4 000 EPG
S. mansoni	1–99 EPG	100–399 EPG	≥ 400 EPG
S. haematobium	1–50 eggs/10 ml of urine		> 50 eggs/10 ml of urine

These infection parameters (prevalence, infection intensity and mixed infections) were calculated at the different administrative levels (national, Regional States/City Administrations, woredas and schools). Subsequently, the point estimates of the different parameters were plotted on a geographical map of Ethiopia using ArcGIS version 10.4 (ESRI, Inc). To gain insights into to the recommended MDA strategy we classified the endemicity of any STH and SCH at the woreda level into low, moderate and high. The criteria for the classification of endemicity, and the corresponding recommended MDA strategies, are summarized in Table 2.

Table 2
The prevalence criteria defining endemicity for soil-transmitted helminths and schistosomes, with corresponding control strategies.

Endemicity	Any soil-transmitted helminth		Any schistosomes	
	Prevalence	Control strategy	Prevalence	Control strategy
Low	≥ 1% and < 20%	Case-to-case treatment	≥ 1% and < 10%	1x MDA/ year for first 2 primary school years
Moderate	≥ 20% and < 50%	1 x MDA / year	≥ 10%and < 50%	1x MDA / 2 years
High	≥ 50%	2x MDA / year	≥ 50%	1x MDA / year

Quality control result analysis for the Kato-Katz thick smear

Quality control of the FECs of any STHs and S. mansoni was performed for 6,042 individuals. For this, Kato-Katz thick smears were re-examined by a team leader. The proportions of both false positives and false negatives were assessed. To this end, we assumed that the team leader was correct. In cases where both results indicated presence of eggs the agreement in egg counts was assessed. There was a disagreement in egg counts where the difference in eggs counts was greater than 10 when the team leader counted fewer than 100, or when the difference in egg counts was more than 20% when the team leader counted more than 100.

Results

Study population

In total 153,238 SAC were screened from 3,142 schools, in 786 of the 817 woredas, across the nine Regional States and two City Administrations. The age of the children ranged from five to 15 years, with a median age of 12 years. The sexes were generally equally represented (ratio of males/females = 0.99). In the following paragraphs we summarize the prevalence and infection intensity for STHs and SCH separately. Then we discuss the occurrence of mixed STH and SCH infections. Finally, we provide an overview of the required MDA strategy at the level of the woreda for STHs and SCH.

Prevalence and infection intensity of STH infections

The unweighted prevalence and mean intensities of infection, for each of the parasites studied, are summarized in Table 3. The overall prevalence of infection with any STH was 21.7%. The most prevalent STH species was A. lumbricoides (12.8%), followed by hookworms (7.6%) and T. trichiura (5.9%). There was a large variation in prevalence across the different Regional States and City Administrations (Table 3). For any STH, the prevalence ranged from 1.7% (Addis Ababa City) to 58.1% (Gambela). For the different STH species separately the prevalence ranged from 0.1% (Harari) to 45.2% (Gambela) for Ascaris, from 0.0% (Addis Ababa City Administration) to 21.5% (Gambela) for hookworms and from 0.0% (Afar, Dire Dawa City Administration and Harari) to 15.3% (SNNPR) for T. trichiura.

Table 3
Regional prevalence and intensity of soil-transmitted helminths infections.

	Number of subjects examined	**Any STH (%)**	**A. lumbricoides**			**T. trichiura**			**Hookworms**		
			Prevalence of infection (%)	Mean FEC (EPG)	Prevalence of moderate-to-heavy intensity infections (%)	Prevalence (%)	Mean FEC (EPG)	Prevalence of moderate-to-heavy intensity infections (%)	Prevalence (%)	Mean FEC (EPG)	Prevale of modera to-heav intensit infectio (%)
Addis Ababa	2,718	1.7	1.2	7.2	0.0	0.6	0.5	0.0	0.0	0.1	0.0
Afar	2,377	2.2	2.0	1.3	0.0	0.1	0.1	0.0	0.2	0.1	0.0
Amhara	25,246	14.3	8.0	104.0	0.4	0.6	1.2	0.0	6.5	15.9	0.0
Benishangul-Gumuz	3,109	10.3	0.8	2.8	0.0	0.7	1.1	0.0	9.3	17.1	0.0
Dire Dawa	1,701	2.3	1.6	1.0	0.0	0.1	0.0	0.0	0.8	0.8	0.0
Gambela	2,977	58.1	45.2	520.5	0.6	6.3	3.4	0.0	21.5	49.3	0.1
Harari	1,804	3.0	0.1	0.1	0.0	0.1	0.1	0.0	2.8	5.1	0.0
Oromiya	62,520	16.7	9.3	154.2	0.9	4.6	9.9	0.2	5.6	22.0	0.2
SNNPR	37,544	42.4	25.9	820.5	5.2	15.3	31.6	0.3	13.5	40.9	0.2
Somali	966	38.0	36.4	134.2	0.0	1.2	0.9	0.0	5.5	8.0	0.0
Tigray	12,276	5.4	2.2	6.9	0.0	0.2	0.3	0.0	3.3	5.4	0.0
Total	153,238	21.7	12.8	292.8	1.7	5.9	12.1	0.2	7.6	23.5	0.1

Figure 1 illustrates the prevalence at the woreda level for any STH. In general, the distribution of any STH is more prevalent in the south, southwest and north of Ethiopia, and less prevalent in the east of the country.

The overall mean FEC was 293 EPG for A. lumbricoides, 24 EPG for hookworms and 12 EPG for T. trichiura. As illustrated by Table 3, there was a large variation in mean FEC for the different STH species across the Regional States and City Administrations. For A. lumbricoides the mean FEC ranged from 0.1 EPG (Harari) to 821 EPG (SNNPR), and from 0.1 EPG (Addis Ababa and Afar) to 49EPG (Gambela) for hookworms. For T. trichiura, the mean FEC ranged from < 0.1 EPG (Dire Dawa City Administration) to 32 EPG (SNNPR). Overall, the prevalence of moderate-to-heavy intensity of any STH infection was 2%. For the STH species separately, the proportions were 1.7%, 0.2% and 0.1% for Ascaris, Trichuris and hookworms, respectively. Figures 2 to 4 show the prevalence of moderate-to-heavy infections for A. lumbricoides (Fig. 2), T. trichiura (Fig. 3), and hookworms (Fig. 4). The southern, south-western and northern parts of the country have more infections of moderate-to-heavy intensity.

Prevalence and infection intensity of SCH infections

The overall prevalence of any SCH equalled 3.8%. S. mansoni was more prevalent (3.5%) than S. haematobium (0.34%). Similarly, for SCH, there was large variation in prevalence across the different Regional States and City Administrations (Table 4), ranging from 0.1% (Addis Ababa City Administration) to 15% (Benishangul-Gumuz). S. haematobium was more prevalent in Somali (60%), Benishangul-Gumuz (1.8%) and Amhara (1.1%).

Table 4
Regional prevalence and intensity of schistosome infections

	Number of subjects examined	**S. mansoni**			**S. haematobium**		
		Prevalence (%)	Mean FEC (EPG)	Prevalence of moderate-to-heavy intensity infections (%)	Prevalence (%)	Mean FEC (EPG)	Prevalence of moderate-to-heavy intensity infections (%)
Addis Ababa	2,718	0.1	4.5	0.1	0.0	0.0	0.0
Afar	2,377	0.3	0.7	0.1	0.0	0.1	0.0
Amhara	25,246	3.0	4.2	1.1	1.1	0.0	0.0
Benishangul-Gumuz	3,109	14.9	20.6	5.2	1.8	1.0	2.0
Dire Dawa	1,701	6.2	12.5	2.6	0.0	0.0	0.0
Gambella	2,977	9.2	7.2	2.1	0.0	0.0	0.0
Harari	1,804	6.0	11.9	2.9	0.0	0.0	0.0
Oromiya	62,520	2.1	5.5	0.9	0.0	0.0	0.0
SNNPR	37,544	2.6	7.2	1.2	0.0	0.0	0.0
Somali	966	5.9	5.4	1.3	60.0	35.0	30.0
Tigray	12,276	10.8	16.7	3.8	0.0	0.0	0.0
Total	153,238	3.5	7	1.4	0.3	0.1	0.1

The prevalences at the woreda level are illustrated in Fig. 5 for S. mansoni and in Fig. 6 for S. haematobium. The overall mean egg count was 7 EPG for S. mansoni and 0.1 eggs/10 ml of urine for S. haematobium (Table 4). The mean FEC for S. mansoni ranged from < 1 EPG (Afar) to 21 EPG (Benishangul-Gumuz). For S. haematobium the mean egg count ranged from < 0.1eggs/10 ml (Afar) to 35eggs/10 ml (Somali). The prevalence of moderate-to-heavy intensity of any SCH infections equalled 1.6%. For the schistosome species separately, the proportions were 1.4% for S. mansoni and 0.1% for S. haematobium. The prevalence of moderate-to-heavy infections are shown for S. mansoni in Fig. 7 and for S. haematobium in Fig. 8. Moderate-to-heavy intensity infections were more prevalent in the west and north of the country for S. mansoni and in the east for S. haematobium.

Mixed infections

In total, 10,609 out of the 36,295 infected children harboured infections with two or more helminths. Mixed infections with two, three and four different helminth species were observed in 89.2%, 10.2% and 0.6% of the 10,609 children, respectively. The different mixed infection patterns are summarized in Table 5. The most prevalent mixed infections were Ascaris infections mixed with either Trichuris or hookworms, accounting for more than 50% of the mixed infections.

Table 5
Summary of the mixed infections (individuals infected with two or more helminth species).

	Number (%)
Four helminth species	65 (0.6)
S. mansoni + A. lumbricoides + T. trichiura + hookworms	65(100)
Three helminth species	1,080(10.2)
S. mansoni + A. lumbricoides + T. trichiura	169(15.6)
S. mansoni + A. lumbricoides + hookworms	128(11.9)
S. mansoni + T. trichiura + hookworms	103(9.5)
A. lumbricoides + T. trichiura + hookworms	680(63)
Two helminth species	9,464 (89.2)
S. mansoni + A. lumbricoides	534(5.6)
S. mansoni + T. trichiura	528(5.6)
S. mansoni + hookworms	641(6.8)
A. lumbricoides + T. trichiura	3,953(41.8)
A. lumbricoides + hookworm	2,527(26.7)
T. trichiura + hookworm	1,281(13.5)

MDA strategy for STH and SCH

Table 6 summarizes the endemicity of STH and SCH across the different woredas. The results in this table, combined with the MDA recommendations by WHO in Table 2, were used to draw up the recommended MDA strategy for STHs and SCH in Ethiopia. For STHs, 215 out of 786 (27.4%) woredas require MDA once a year and 279 (35.5%) require MDA twice a year. For SCH, MDA once a year is recommended for 69 (8.8%) woredas and once every two years for 153(19.5%) woredas. Large-scale treatment for STH and SCH was not warranted for 45 and 374 woredas respectively.

Table 6
Numbers of low, moderate, and heavy endemic woredas for soil-transmitted helminths and schistosomes.

Woreda	Soil-transmitted helminths (%)	Schistosomes (%)
Uninfected	45(5.7)	374(47.6)
Low	247(31.4)	190(24.2)
Moderate	215(27.4)	153(19.5)
High	279(35.5)	69(8.8)
Total	786 (100%)	786 (100%)

Quality control of Kato-Katz thick smears

Table 7 summarizes the results of the quality control of the Kato-Katz thick smears. In total, 6,042 Kato-Katz thick smear slides were re-examined by the team leaders. Overall, there was an agreement in test result in 91% of the positive cases (9% false negatives) and 98% of the negative cases (< 2% false positive cases). The numbers of false negatives were relatively high for Trichuris (8.7%) and low for hookworms (3.0%). Among the positive cases, there was an agreement in 93% of the cases. The agreement was high for S. mansoni (98.4%) and relatively low for Ascaris (93.7%).

Table 7
Quality control results across 6,042 Kato-Katz thick smear.

Helminth	False positive test result (%)	False negative test result (%)	Discrepancies in egg counts (%)
A. lumbricoides	0.9	5.5	6.3
T. trichiura	0.8	8.7	2.7
Hookworm	1.5	3.0	2.2
S. mansoni	0.2	4.3	1.6

Discussion

WHO has set the ambitious goal to cover at least 75% of SAC in need of treatment against STHs and SCH in all endemic countries by 2020[4, 22–24]. In order to roll out an MDA program, detailed disease maps are pivotal to ensure that areas most in need of MDA are covered, and to avoid large-scale deworming being initiated in areas were disease is rare or absent. Although historical data highlight that Ethiopia is endemic for both STHs and SCH [5–7], up-to-date maps are currently missing. This study reports the results of the nationwide survey that was designed to provide up-to-date estimates of the disease distributions at the woreda level, which in turn will inform the national control program against STHs and SCH.

The results of the present study confirm that both STHs and SCH are prevalent in Ethiopian SAC. The overall prevalence for any STH in this population was estimated to be 21.7%, and for SCH the prevalence estimate is 3.8%. To our knowledge, this will be the first large-scale survey conducted at national level. Our regional level prevalence for Amhara region is lower than the prevalence report by Andrew and colleagues across the different zones and woredas of the Amhara regional states (STH: 36.5, SCH: 6.9%)[8]. This difference might be explained by differences in diagnostic methods used (Kato-Katz thick smear vs. formol ether concentration), study population (SAC vs. community). Our 60% prevalence for S. haematobium in Somali regional state is in agreement with the previous reports by Negussu et al 2013[13], but it remains unclear why this region is hyper endemic for SCH. There have been many small-scale studies in different parts of the country that reported prevalence for STH and SCH[9, 11, 12, 14, 15, 25]. However, none of those studies were conducted at a national scale.

The different disease maps highlight that there are large geographical variations in prevalence and infection intensity (Figs. 1–8). This variation can be explained by a variety of factors, including but not limited to differences in climate, population density, and WASH. Alongside this study, associations between WASH and STHs/SCH infections were assessed and reported by Grimes & colleagues [21]. They concluded that better sanitation was associated with significantly lower A. lumbricoides infection intensities and borderline significant lower hookworm infection intensities. Better hygiene was associated with significantly lower hookworm intensities. However, no significant differences were observed when comparing sanitation and S. mansoni or T. trichiura infections, and comparing hygiene and A. lumbricoides or T. trichiura infections. Figure 1 highlight that STH-endemic woredas are primarily located in the south, south-west, and north of the country. Dense population and agricultural activities in these areas potentially result in increased exposure to contaminated soil. In the eastern part of the country infections are less abundant, and this may be explained by a dry and arid climate, which does not favour the transmission of these parasites.

The success of the STH and SCH control programs can be measured by the reduction in moderate-to-heavy intensity infections. Ultimately, WHO aims to eliminate these diseases as a public health problem, which is defined as a prevalence of moderate-to-heavy intensity infections less than 1%. The prevalence of overall moderate-to-heavy infections above 1% for both STH and SCH confirms the importance of the diseases as public health problems in Ethiopia[26]. Yet, it was striking that, despite the lack of large-scale MDA programs and the abundance of STH and SCH infections, the prevalence of moderate-to-heavy intensity infections was already low (STH: 2%; SCH:1.6%).

The study highlights that 59.3% and 26.7% of the woredas are endemic for STH (prevalence ≥ 20%) and SCH (prevalence ≥ 10%) at a level requiring MDA, meaning that 18 and 14 million SAC are in need of regular deworming through MDA campaigns for STH and SCH, respectively. The presence of STH and SCH co-infections shows the efficiencies that might be gained with an integrated control strategy. Indeed, in the past, integrated control has led to impressive reductions in prevalence and related morbidity [27]. In addition to integrating control against various parasites, the delivery of different types of parasite control might also be integrated. There are now recommendations to combine MDA with other interventions such as WASH to break parasite transmission and reach elimination[28].

The large areas of overlap in the distributions of the different STH species in Ethiopia could pose a challenge to future control programs. Currently, the country is using mebendazole in all areas. However, previous study indicated a differential efficacy between albendazole and mebendazole across STHs. Both drugs are equally efficacious against Ascaris, but albendazole is more efficacious against hookworms whereas mebendazole is more efficacious against T. trichiura infections [29].

Following this national survey, Ethiopia has now distributed drugs for 3 years (2015–2018). Overall, the coverage has been high (> 75%) for both sets of diseases in all woredas. In addition, 175 sentinel schools that represent the different levels of disease endemicity are currently periodically evaluated for the prevalence and intensity of both STH and SCH. These sentinel schools are also subjected to a variety of operational research activities in collaboration with national and international partners, with the aim of further improving the control program.

Ethiopia mobilized sufficient financial resources through a range of partners to support its nationwide survey to map the baseline distribution of both diseases. However, the cost of the survey was substantial, and there is a clear need to identify ways to reduce the cost of NTD mapping, and reduce the dependency on external partners. In response to this, we verified whether the examination of pooled samples rather than individual samples could be a potential cost-saving strategy in large-scale epidemiological surveys along this nationwide survey[30]. The outcome of this study highlighted that a pooled examination strategy reduced the laboratory time by 70% but only resulted in an11% cost reduction. Moreover, we also recommended pooling for the rapid assessment of infection intensity. However, further investigation is required to determine field procedures and statistical methods for optimal implementation of sample pooling for prevalence assessment.

This study has a variety of limitations. First, the use of single instead of duplicate Kato-Katz thick smear has a clear impact on the prevalence results, as single Kato-Katz thick smear is known to be less sensitive than double Kato-Katz thick smear [31]. We opted for a single Kato-Katz for both practical and financial reasons. In general, more children and fewer slides is better than fewer children and more slides. The impact of a single slide on estimates of infection intensity (mean FEC and proportion of moderate-to-heavy infections) is probably less pronounced, since mainly the lowest levels of egg excretion are missed[32]. Second, the school selection was biased towards SCH. This strategy was opted, because in contrast to STHs, SCH has a more focal distribution. Although this will have an impact on our estimates of SCH prevalence, we do not expect that this has a major impact on those for the prevalence of STH. Another aspect that may have an impact on the prevalence and hence the decisions made, is the sample size (5 schools per woreda and 50 children). Although this is the sample size recommended by WHO, it has been shown that this strategy might not be optimal, resulting in unnecessary administrating drugs or withholding administration of drugs to children in need of treatment, particularly for focally distributed diseases such as SCH [33].

In conclusion, the nationwide mapping confirms that Ethiopia is endemic to STH and SCH. The finding from this mapping warrants MDA to SACs living in areas that qualify for treatment. We recommend STH and SCH mapping that includes preschool age children, adolescent and adult populations to scale up the control program and fine twined mapping hot spot areas for SCH.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethiopian Public Health Institute Scientific and Ethical Review Office (reference number SERO-128-4-2005) and the Institutional Review Board of Imperial College London (reference number ICREC_8_2_2). Official letters were written by the Ethiopian Public Health Institute (EPHI) to the Regional Health and Education Bureaus to obtain regional consent. The school head provided written consent on behalf of the students' families or guardians as the survey falls under the mandate of the Ministry of Health. Students provided verbal assent to be included in the survey. All students included in the survey were provided with a single oral dose of 500 mg mebendazole (Janssen Pharmaceutical NV, Beerse, Belgium). In addition, students who tested positive for schistosomiasis were provided with 40 mg kg/body weight (measured by a dose-pole) of praziquantel (Merck KGaA, Darmstadt, Germany) [1,4].

Consent for publication

During the institutional Ethical approval we declared the finding of the survey will be published on peer reviewed journal and got the institutional approval.

Competing interests

The authors declare that they have no competing interests

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Figures

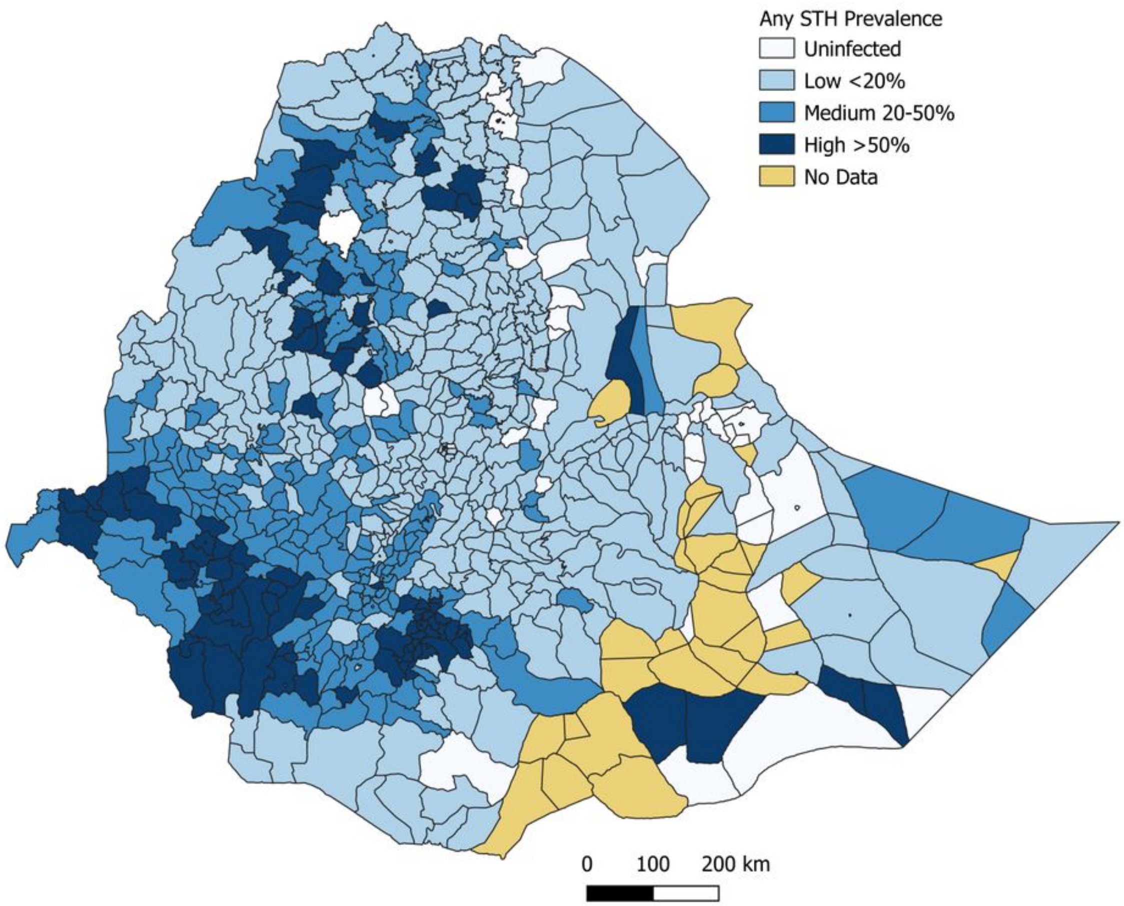

Figure 1

Distribution of any soil-transmitted helminth infections at the woreda level, Ethiopia 2013-2015. The percentage of individuals in each woreda with at least one STH egg found in the Kato-Katztest.www.gadm.org/ is the source of the administrative boundaries.

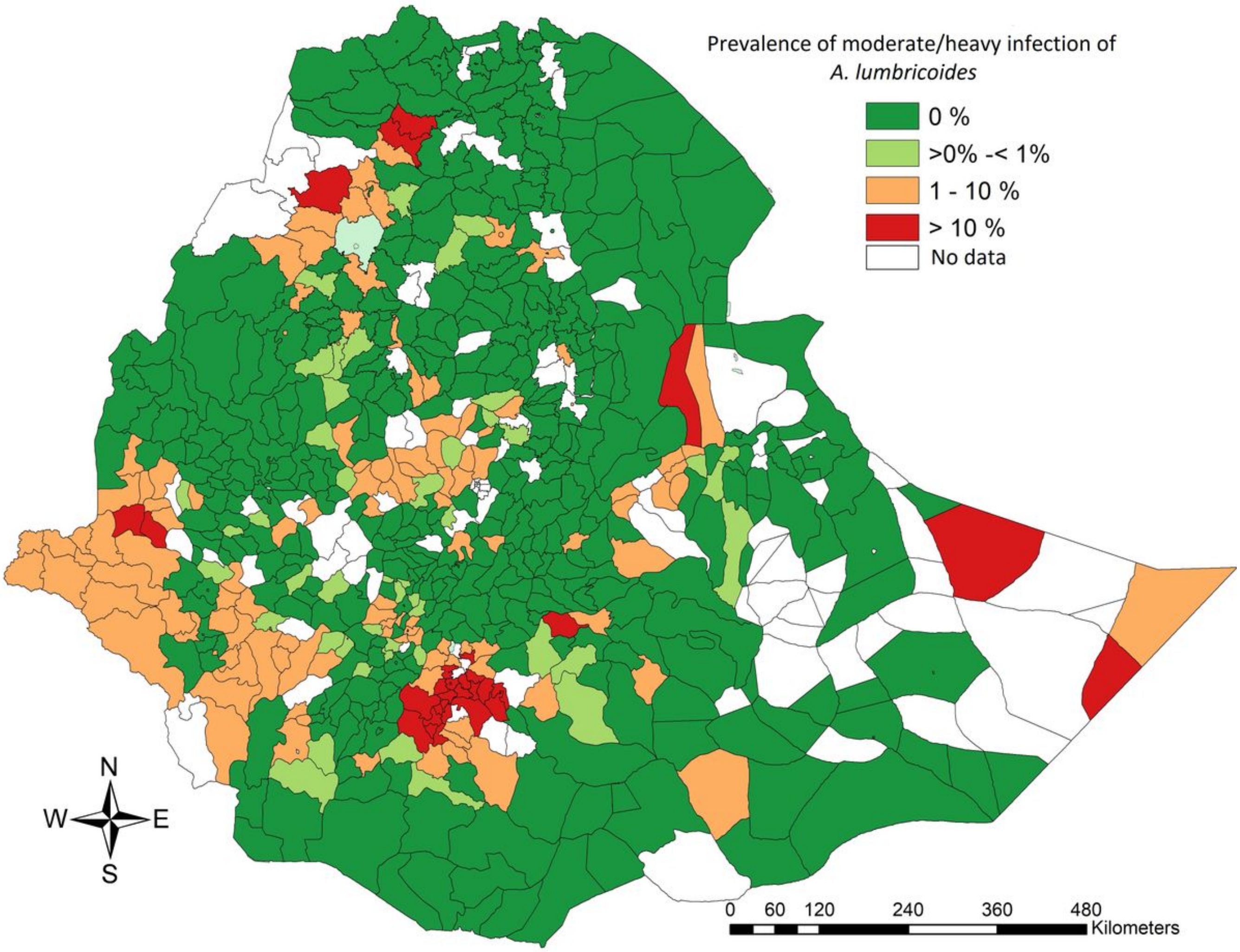

Figure 2

Distribution of Ascaris lumburicoides moderate-to-heavy intensity infections in school-age children, Ethiopia 2013-2015. Intensity classes are categorized according to WHO intensity classification for A.lumbricoides egg counts. www.gadm.org/ is the source of the administrative boundaries.

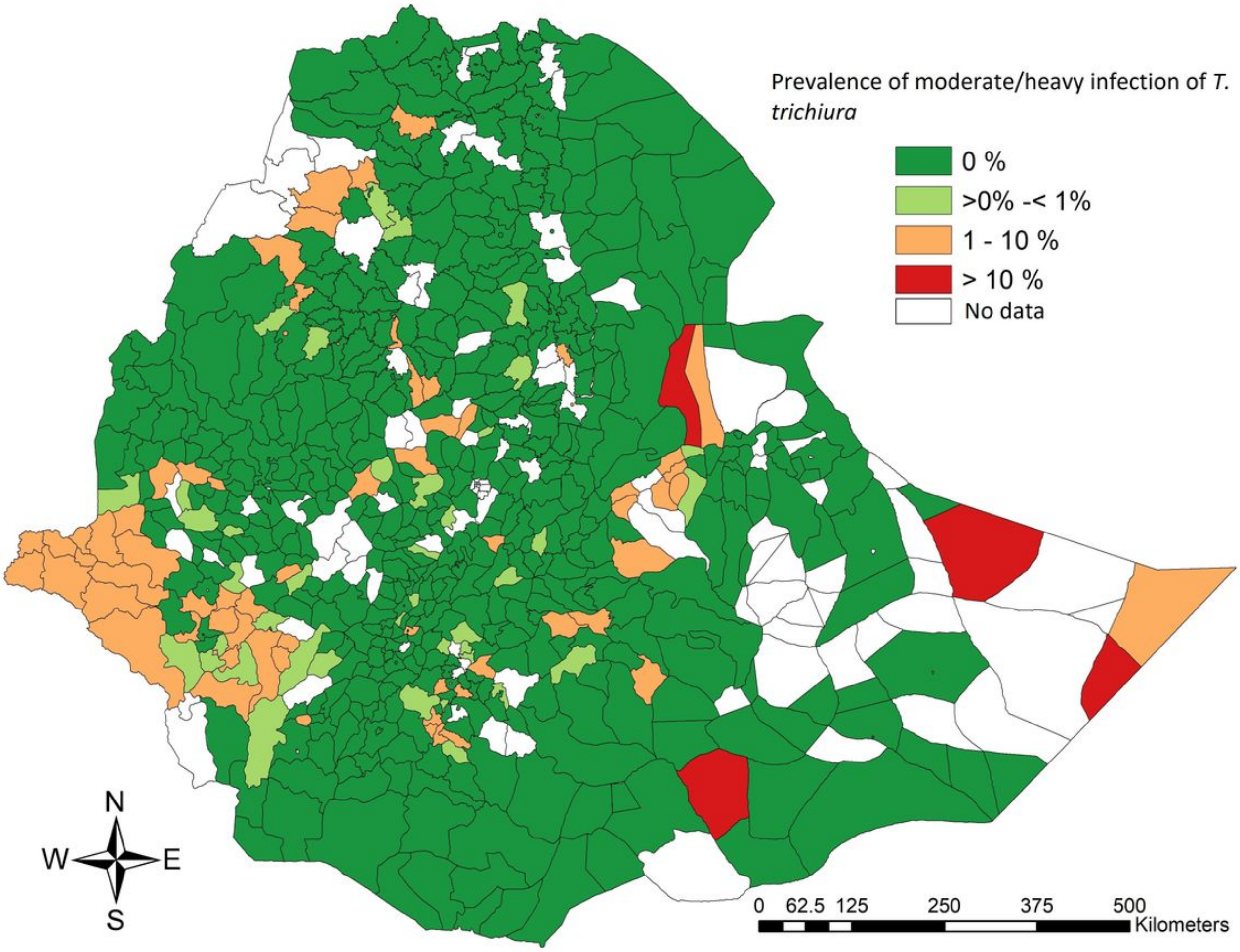

Figure 3

Distribution of Trichuris trichiura moderate-to-heavy intensity infections in school-age children, Ethiopian 2013-2015. Intensity classes are categorized according to WHO intensity classification for T. trichiura egg counts. www.gadm.org/ is the source of the administrative boundaries.

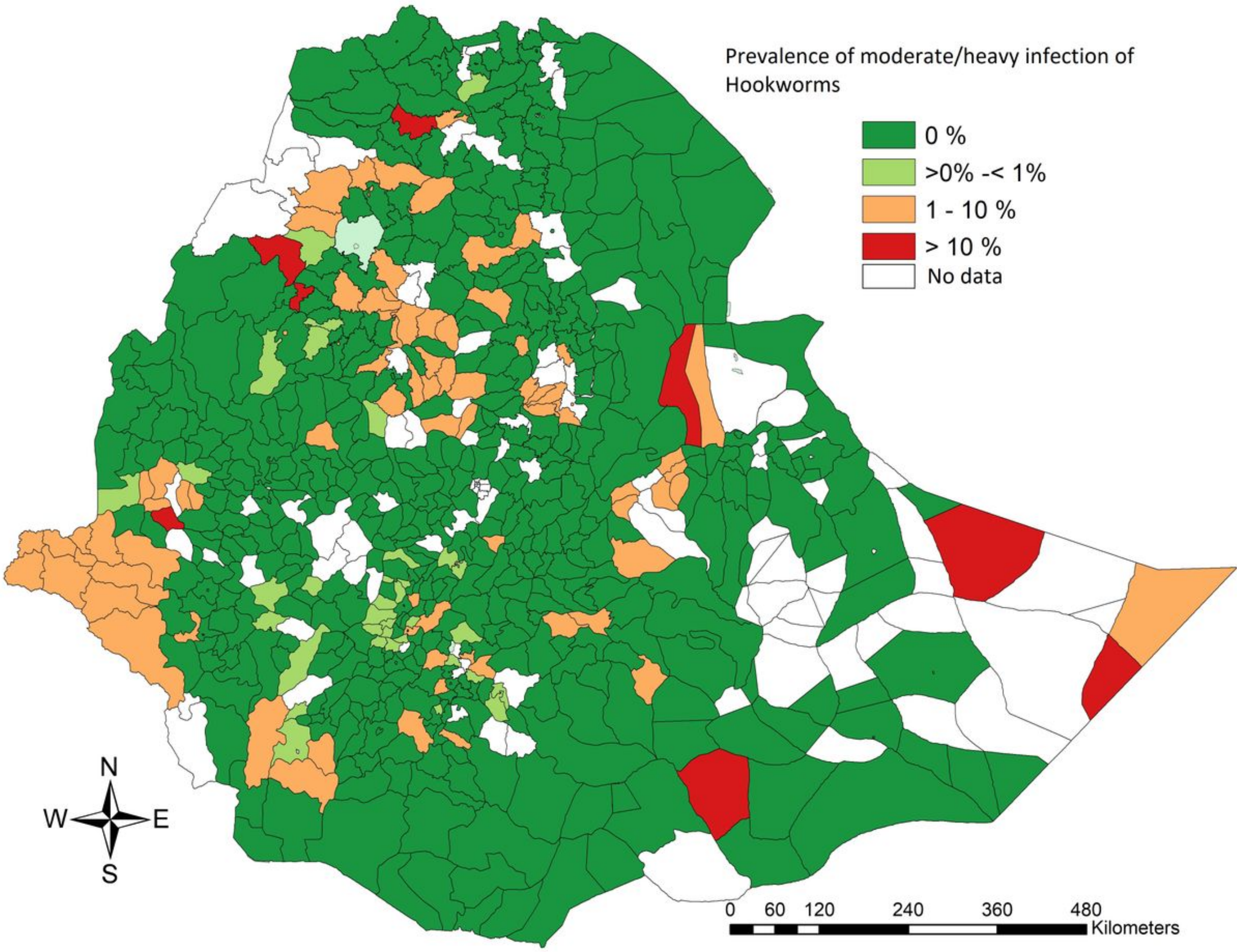

Figure 4

Distribution of hookworm moderate-to-heavy intensity infections in school-age children, Ethiopia 2013-2015. Intensity classes are categorized according to WHO intensity classification for hookworm egg counts. www.gadm.org/ is the source of the administrative boundaries.

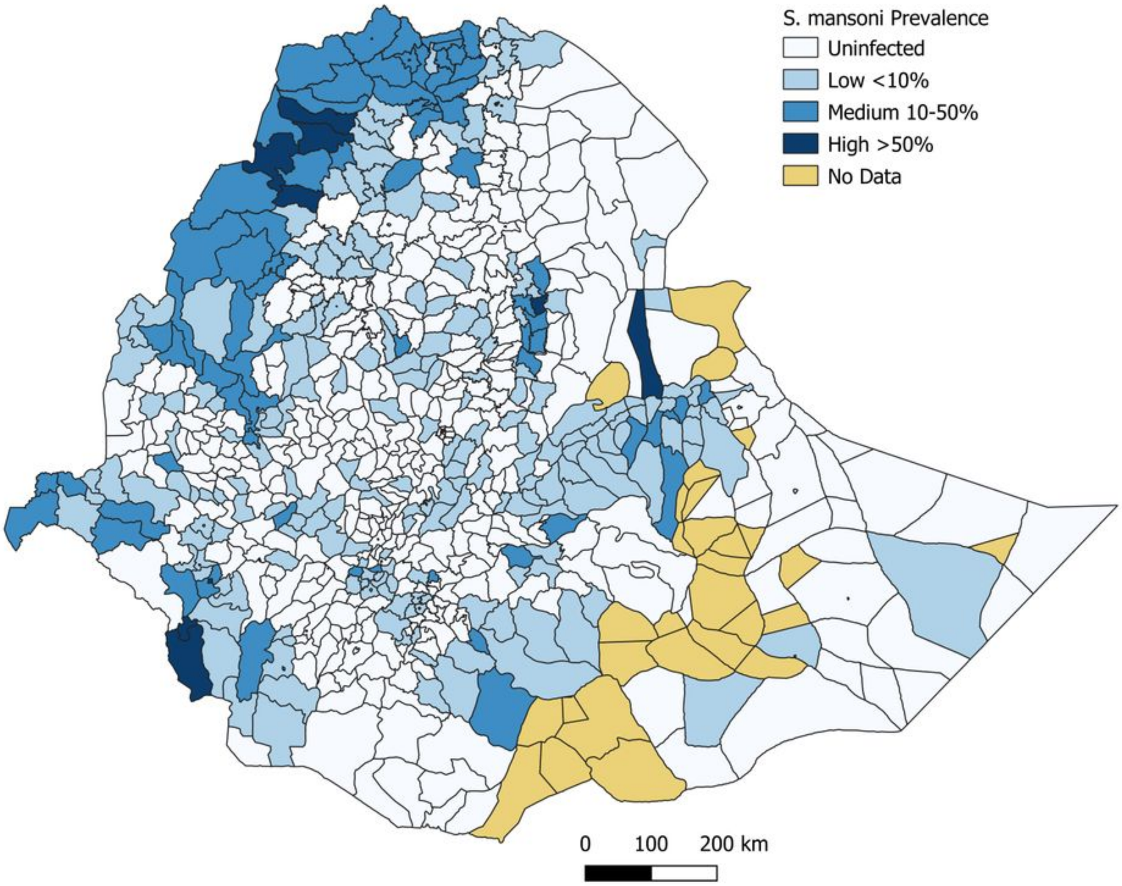

Figure 5

Distribution of Schistosoma Mansoni infections at the woreda level in school-age children, Ethiopia 2013-2015. The percentage of individuals in each woreda that at least one S. mansoni egg found in the Kato-Katztest.www.gadm.org/ is the source of the administrative boundaries.

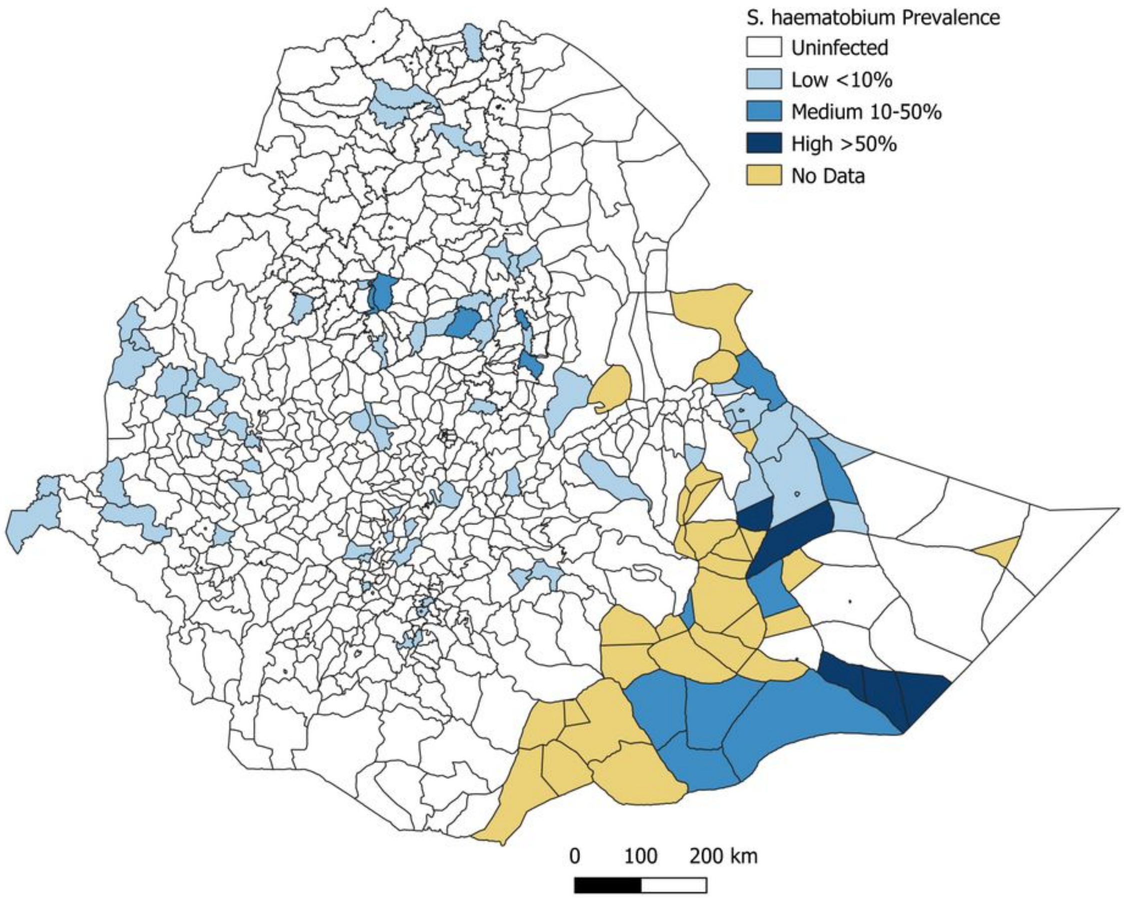

Figure 6

Distribution of Schistosoma haematobium infections at the woreda level in school-age children, Ethiopia 2013-2015. The percentage of individuals in each woreda that at least one S. haematobium egg found in the urine filtration.www.gadm.org/ is the source of the administrative boundaries.

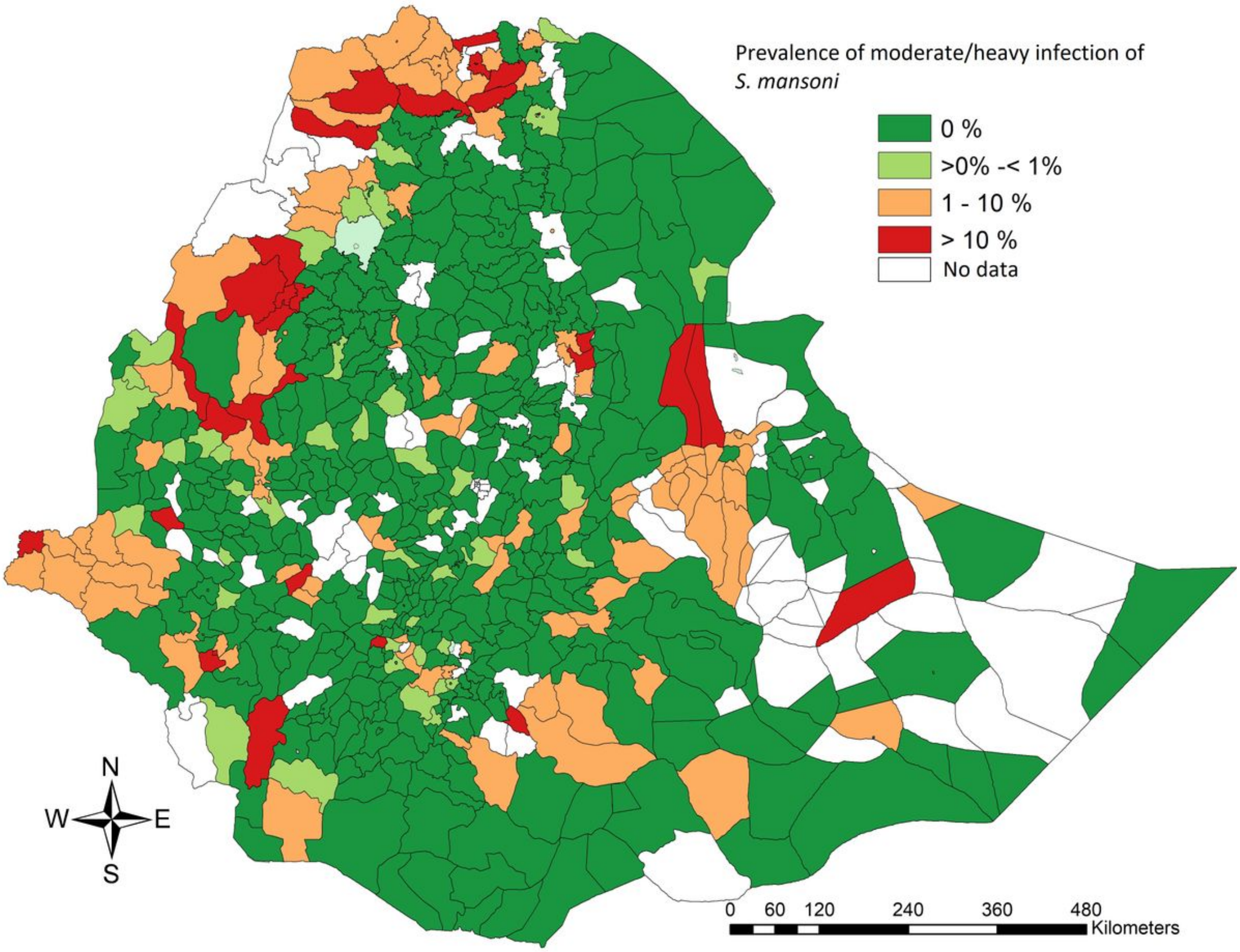

Figure 7

Distribition of Schistosoma mansoni, moderate-to-heavy intensity infections in school-age children, Ethiopian 2013-2015. Intensity classes are categorized according WHO intensity classification for S.mansoni.www.gadm.org/ is the source of the administrative boundaries.

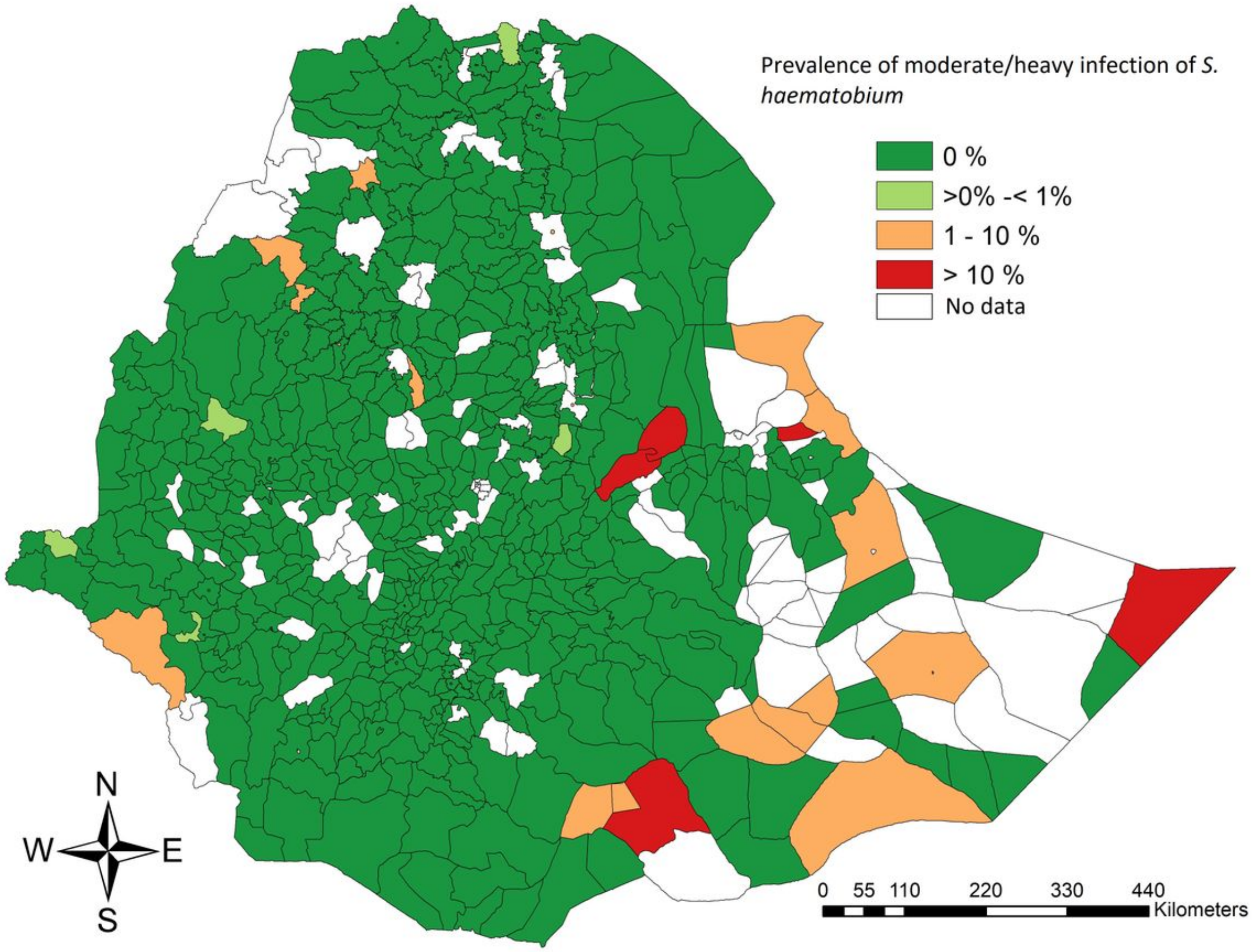

Figure 8

Distribution of Schistosoma haematobium, moderate-to-heavy intensity infections in school-age children, Ethiopia2013-2015. Intensity classes are categorized according to WHO intensity classification for S. haematobium based on the eggs per 10ml of urine. www.gadm.org/ is the source of the administrative boundaries.

Supplementary Files

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- S1Fig.surveycoordination.docx