Epidemiology of intestinal parasitic infections in preschool and school-aged Ethiopian children: A systematic review and meta-analysis

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Abstract

Background: Numerous studies have been carried out on assessing the prevalence of intestinal parasites infections (IPIs) among preschool and school age children in Ethiopia, however, there was no study to gather and systematically analyze this information for policy makers. Methods: We searched Medline via PubMed, Scopus, Science Direct, Web of Science (ISI), and Google Scholar and local peer-reviewed journals published from inception to 2019 for studies describing prevalence of IPIs among preschool and school age children. We conducted meta-regression to understand the trend and the source of heterogeneity and pooled the prevalence using ‘metaprop’ command using STATA software (Intercooled, version 14, STATA Corp, College Station, TX). Results: Eighty three (83) studies examining 56,786 fecal specimens were included. The prevalence of IPIs was 48 % (95% CI: 42% to 53%) and showed a gradual, but significantly decreasing trends 17% (95% CI: 2.5% to 32%) for each consecutive 6 years) and was similar in males and females. The pooled prevalence in years 1997–2002, 2003–2008, 2009–2014 and >2014 was 71% (95% CI: 57% to 86%), 42% (95% CI: 27% to 56%), 48% (95% CI: 40% to 56%) and 42% (95% CI: 34% to 49%), respectively. Poly-parasitism was observed in 16% (95% CI: 13% to 19 %,) of children while, single parasite infection was observed in 36 %(95% CI: 30% to 41%). Conclusion: IPIs are highly prevalent and well distributed across the regional states of Ethiopia. Southern and Amhara regional states carry the highest burden. We observed a gradual, but significant decreasing trends in prevalence of IPIs among Ethiopian children over the last two decades.

BACKGROUND
Parasitic infections caused by intestinal helminths and protozoan are among the most prevalent infections in developing countries carrying high burden of morbidity and mortality in these areas[1]. Specifically, economically disadvantaged children living in tropical and sub-tropical regions with a limited or no access to safe drinking water, inadequate sanitation, and substandard housing are the most affected ones [2]. Epidemiological evidence suggests that an estimated over one billion people in the world, majorly children were infected with intestinal parasites caused by helminthes and protozoa [3]. Majority of the infections were due to Ascaris lumbricoides, hookworm, and Trichuris trichiura[4, 5]. More than 267 million preschool-age children and 568 million school-age children live in areas where these parasites are intensively transmitted [6]. Cryptosporidium species, Entamoeba histolytica and Giardia duodenalis were the most common protozoan infections in children under five years in sub-Saharan Africa [7].

The regional distribution and prevalence differences of IPIs among children are mainly due to differences in degree of fecal contamination of water and food, climatic, environmental and socio-culture[8-10]. The prevalence among under-five, preschool and school children were reported as 17.7% in Riyadh, Saudi Arabia[11], 52.8% in an urban slum of Karachi, Pakistan [12], 19.6% in Zambia [13] and 30% in Khartoum, Sudan [13]. In Ethiopia, prevalence varies across the regions in the country. For instance, the prevalence was 85.1% in Wondo Genet (Southern region) [14], 48.1% in Aynalem village (Tigray region) [15], 17.4% in Debre Birhan (Amhara region) [16], 26.6% in Hawassa (Southern region) [17], 24.3% in Wonji Shoa Sugar Estate (Oromia region) [18], 18.7% in Woreta (Amhara region) [19], 25.6% in Dembiya (Amhara region) [20] and 41.1% in Jimma town (Oromia region) [21].
School-age children are the most affected ones due to their habits of playing or handling of infested soils, eating with soiled hands, unhygienic toilet practices, drinking and eating of contaminated water and food [22]. Intestinal parasite infections lead to malnutrition, mal-absorption, anemia, intestinal obstruction, mental and physical growth retardation, diarrhea, impaired work capacity, and reduced growth rate constituting important health and social problems [10, 18, 23, 24].

Numerous epidemiological studies have been performed on assessing the prevalence of IPIs among children in Ethiopia, but there is lack of systematically gathered and analyzed information for police-makers. Therefore, the aim of this systematic and meta-analysis was to provide a summary on prevalence, geographical distribution and trends of IPIs among preschool and school-age children in Ethiopia.

METHODS

Search strategy and data extraction

The search were carried out in Medline via PubMed, Scopus, Science Direct, Web of Science and Google Scholar using searching terms “intestinal parasite infection” OR “helminth” OR “protozoa” AND “Ethiopia”. Searching was carried out on articles published from 1997 to March, 2019 and limited human studies with language restriction to English. A manual search for additional relevant studies using references from retrieved articles and related systematic reviews was also performed to identify original articles we might have missed. Conference abstracts and unpublished studies were excluded. We did our analyses according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)
Participants, inclusion and exclusion criteria

Two authors independently (LCH & DE) assessed the inclusion criteria and disagreement was solved by discussion with the third author (ZM). We included the studies if they met the following criteria: the study design was an observational study (prospective cohort, case-control, retrospective cohort, or cross-sectional) or controlled clinical trial which documented the baseline prevalence or incidence of IPIs. We included all studies reported the rate or proportion of IPIs in preschool and/or school age children or both. We excluded studies reporting case reports, case series, studies that compared the sensitivity and specificity of different methods used for diagnosis of intestinal parasites and studies not reported either prevalence or incidence of IPIs as outcome of interest. The terms preschool and school-age children were defined according to the original studies. Accordingly, preschool-age children were defined as children of age below 5 years while, school-age children were children of age 5 and above. Poly-parasitism was defined as concurrent infection with different species of intestinal parasites either helminths or protozoa.

Data extraction and Quality assessment

The two authors (LCH and DE) defined protocol for data extraction and assessed them independently for eligibility and disagreements were resolved by discussion with the third author (ZM). We extracted information on name of the first author and year of publication, study design, population studied (preschool age children, school age children or both), gender, region & sites of study, Method (s) for identification of the parasites, total sample size and the number of the positives (percentage). The Grading of Recommendation Assessment, development and
Evaluation (GRADE) approach was used to assess the overall quality of evidence[26]. Accordingly, studies were given one point each if they had probability sampling, larger sample sizes of more than 200, and repeated detection and up to four points could be assigned to each study. Publications with a total score of 3-4 points were considered as high quality, whereas 2 points represented moderate quality and scores of 0-1 represented low quality.

**Statistical analysis**

We used forest plots to estimate pooled effect size and effect of each study with their confidence interval (CI) to provide a visual summary of the data. A random-effects model was used in this meta-analysis because of anticipated heterogeneity. All reported P values were 2-sided and were statistical significant if P < 0.05. Statistical heterogeneity among studies was expressed as the P value (Cochran’s Q statistic), where a P < 0.05 and I² ≤ of 25-50% were considered as low heterogeneity and I² > 50% indicated substantial heterogeneity. We also used Begg’s Funnel plot and Egger’s regression test for evaluating the possibility of publication bias. A potential source of heterogeneity was investigated by subgroup and meta-regression analysis. The factors included were geographical regions and cities of Ethiopia, age of children (Preschool vs. school age children), and years of publication (1997-2002, 2003-2008, 2009-2014 and > 2014). We conducted meta-analysis using ‘metaprop’ command using STATA software, version 14, STATA Corp, College Station, TX.

**Results**

**Literature searches and selection**

We identified systematically 1,198 publications, of which 83 were eligible for
inclusion in the final analyses. The details of our search strategy were depicted in Figure 1. Our initial search of electronic databases such as Medline via PubMed, Scopus, Science direct, Web of Sciences and Google scholar yielded 1195 articles and 3 articles manually from which 186 records remained after removing 1012 duplications. Up on screening the articles, 99 articles were further excluded; 90 were irrelevant because they were not specifically about preschool or school-age children, 6 studies were about sensitivity and specify of diagnosis of IPIs, 3 articles were review articles. Up on further access to the full texts of 87 articles, 4 were excluded for the following reasons; 2 were meta-analyses and 2 articles lacked outcome of interest. Finally, 83 published between 1997 and 2019 fulfilling the inclusion criteria were included in the final analyses.

The sample size of the included studies ranged from 100[27] to 15455[28] with a total number of 56,786 participants[14, 16, 17, 21, 24, 27-40, 42-44, 46-63, 65-91, 93-107]. Most of the studies were reported from Amhara regional 33(40%) followed by Oromia region 21(25%). The rests were reported from South region 18(22%), Tigray region 9(11%), Benishangul-Gumuz region 1(1%) and Addis Ababa city 1(1%).

With regard to the study design, majority of the studies were cross sectional in design (79 studies), 2 were controlled clinical trials, 2 were prospective follow up cohort studies and 1 was case-control. Sixty six studies were about IPIs in school age children, 13 were in preschool age children (under-five) and 4 were studies involved both preschool and school age children. According to our quality assessment criteria, 34 publications were of high quality with a score of 3, 12 had a score of 2 indicating moderate quality and the remaining 37 were of low quality with a score of zero or one [Table1 at the end of manuscript on page 26-31].

Prevalence estimate and heterogeneity analysis
A total of 27,354 of the 56,786 children examined during the period under review were infected with one or more species of intestinal parasites yielding an overall prevalence of (n = 27,354) 48 % (95%CI: 42% to 53%) with substantial heterogeneity ($I^2 = 99.50\%$, regression coefficient: -0.23, 95% CI: -0.38 to -0.09, $p = 0.002$, Fig. 2). A range of parasites were detected in the studies including *Ascaris lumbricoides*, *Hookworm*, *Trichuris trichuria*, *Strongyloides stercoralis*, *Enterobius vermicularis*, *Schistosoma mansoni*, *Hymenolepis nana*, *Taenia species*, *Giardia lamblia/intestinalis/duodenalis*, *Entamoeba histolytica/dispar* and *Cryptosporidium species*. Subgroup analysis showed that the prevalence of IPIs was 56% (95%CI : 39% to 73%) in Southern region, 51%(95%CI : 43% to 58%) in Amhara region, 40% (95%CI : 31% to 50%) in Oromia region, and 41%(95%CI : 28% to 54%) in Tigray region Fig. 3 and 4. The age related prevalence was 52% (95%CI: 46% to 58 %,) in school age children and 30% (95%CI: 18% to 34%) preschool age children ($p = 0.002$) as shown in Fig. 5.

The pooled prevalence of IPIs in year 1997–2002, 2003–2008, 2009–2014 and >2014 was 71% (95% CI: 57% to 86%), 42% (95% CI: 27% to 56%), 48% (95% CI: 40% to 56%) and 42% (95% CI: 34% to 49%), respectively [Fig. 6]. We did meta-regression analyses to search for the sources of heterogeneity. The results of the analyses showed that age (regression coefficient: 0.38, 95% CI: 0.15 to 0.60, $p = 0.002$) and year of publication (regression coefficient: -0.17, 95% CI: -0.32 to -0.025, $p = 0.023$) might be sources of heterogeneity, whereas we detected no significance difference in geographical distribution (regression coefficient: 0.025, 95% CI: -0.11 to 0.06, $p = 0.56$) as shown Fig. 7.

**Prevalence of IPIs by area of residence, gender and poly-parasitism status**

Thirteen studies (N=12,356) reported the proportion of IPIs based on residence
The pooled prevalence of overall IPI was not significantly differ between rural and urban areas; rural 22 % (95% CI: 10% to 30%, Additional file 2) and urban 23% (95% CI: 14% to 32%, Additional file 3). Forty two studies (N=36,218) had separate data on the prevalence of IPIs for males and females. The pooled prevalence formales was 24% (95% CI: 20% to 28%,Additional file 4) while, it was 22% (95% CI: 18% to 25%,Additional file 5) for females. Poly-parasitism was observed in 16% (95% CI: 13% to 19%, Additional file 6) of children and 36% (95% CI: 30% to 41%,Additional file 7) of children were infected with a single species of parasite.

DISCUSSION

The pooled prevalence of IPIs in Ethiopian children was 48 % (95% CI: 42 to 53%). The prevalence is higher in Southern (56%) and Amhara regions (51%). We observed a significant decrease in the prevalence of IPIs among children in Ethiopia over the last two decades (22 years). The burden of infection was higher among school-age children compared to preschool-age children (52% vs.30%, p = 0.002), however, it was similar in males and females as well as in urban and rural inhabitants. Poly-parasitism was observed in 16% of preschool and school-age children while, single infection was documented in 36% of the children participated in the study.

The overall pooled prevalence estimate (48%) observed in the present systematic review and meta-analysis is similar to the study from Nigeria (54.8%) [109], Rwanda (50.5%)[110], Afghanistan (47.6% )[111], Syria (42.5%)[112] and in Palestine (40.5%) [113]. However, the finding of this systematic review and meta-analysis is higher than that of Cameron (24.1%) [114], Rwanda (25.4%)[115], Iran (38%)[116], Turkey(31.7%-37.2%)[117] and Egypt (26.5%)[118]. The difference
might be attributed to socio-economic status, poor hygiene and sanitary facilities, weather, climate and environmental factors. For example, a study in Ethiopia showed that *Ascaris lumbricoides* infections were more common in children living in households with lower incomes (prevalence ratio = 6.68, 95% CI = 1.01–44.34) and that *Giardia lamblia* infections were more common in children living in households that used an unprotected water source (prevalence ratio = 1.95, 95% CI = 0.96–3.99) [32]. In addition, most Ethiopian communities have the habit of consuming uncooked meat, which might increase the risk of exposure to human helminths. Many of Ethiopian population where the studies conducted involved in irrigation activities for the cultivation of vegetables during the dry season. This irrigation canals create media for the reproduction of vector snails, which might be the cause of the appearance of endemicity of Trematodes infections in the area. It might also be attributed to the specificity and sensitivity of the diagnostic methods employed by the individual studies.

The meta-regression of prevalence of IPIs over time showed significant decreasing trends in each 6-years block by 17% (95% CI: 2.5% to 32%) and this declined prevalence was probably due to socioeconomic development, improvement in sanitation and large-scale deworming programs. Many studies from around the world have reported a significant decreasing trend in the prevalence of overall IPIs in recent years, such as the global burden of disease study [5], study from Burkina Faso [119], Nepal [120], Brazil [121] and other from 43 Sub-Saharan[122]. Despite many initiatives and efforts to introduce mass deworming program and improvement in water quality and sanitation, IPIs are still prevalent and the decrease in trend is less than that of other countries (Ethiopia 42% in 2016-2019 vs. Nepal 20. 4% in 211-2015 and Brazil 23.8% in 2010-2011). This might be possibly
dueinsufficient financial supports in implementation of the strategies that have been known to reduce the infection such as access to safe water supply, personal hygiene and sanitation, deworming and public health awareness. In addition, lack of political commitment, social and environmental factors might also contribute for the higher prevalence of IPIs in the country. Inadequate community involvement and ownership of control activities are also another possible reason.

The prevalence of IPIs in school age children was (52%), which was significantly higher than in preschool age children (30%). This is similar to the study by Jayarani 2014[123] and Workneh 2014[45], but opposite to the study by Daryani 2017[116]. School children carry the heaviest burden of the intestinal parasite associated morbidity due to their habits of playing or handling of contaminated soils, eating with soiled hands, unhygienic toilet practices, drinking and eating of contaminated water and food [22] compared to preschool children who usually cared by families.

The current control efforts in Ethiopia usually target school-age children, but a significant proportion of preschool age children (30% in this study) were also infected and can be source for the re-infection of treated school-age children. Therefore, it worthy revising the national control program based on regional and national prevalence which included preschool children and other population at risk.

In the present study, the prevalence of IPIs in females (22%) was similar to males (24%), which is similar to the study by Gelaw 2013[47], but in contrast to study by Daryani 2017[116] in Iran. In Iran, report indicated that more females have (30.9%) have IPIs than males (16.5%). The difference might be due to cultural and behavioral difference between the two countries.

The distribution of IPIs in this study was relatively similar in both urban and rural areas. This might be due to absence of proper human waste disposal systems, the
shortage of safe water supply, the social and poor environmental or personal hygiene in many unplanned urban areas in Ethiopia in addition to similarity of eating habit and life style of both urban and rural areas of the country. So far, reports from Africa and South Asia countries are conflicting. Some were reported higher infection rates of IPIs in rural areas compared to urban areas[124-128] and others reported higher rate of infections in urban children[129]. In fact, comparable data on IPIs in urban and rural settings are very limited. For instance, only 13 studies out of 83 studies included in this meta-analysis were reported prevalence of IPIs in both urban and rural areas and therefore, indicating more work to be done in the future to resolve this issue.

We estimated the geographical distribution and identified high risk areas that should be prioritized control interventions, which complement global efforts towards elimination of IPIs infections by 2020. In addition, this work also highlighted the need for survey in areas where data are not available such as Somalia region, Afar region, Harari, Dire Dawa city and Gambella region or scarce (Addis Ababa city and Benishangul-Gumuz region). The essence of current systematic review and meta-analysis of IPIs data analysis among preschool and school-age children in Ethiopian were to support the efforts undertaken to control and eliminate neglected tropical diseasesby nurturing or supplementing useful national epidemiological data. We hope that the findings of current study provide valuable information to the policymakers, National Health Bureau and other concerned bodies about national and regional distribution and their prevalence in Ethiopia preschool and school-children.

There are a few limitations of the present meta-analysis, which may affect the results. First of all, the review protocol is not registered which could be source of
bias. It is prudent to interpret the results of this study as 37 (44.6%) of the included studies were low quality based on our quality assessment criteria. In all of studies included in this review, single stool sample examination were used despite multiple stool samples recommendation for standard diagnosis and therefore, possible underestimation of the prevalence. There is also substantial heterogeneity observed between the studies that affect the interpretation of the results. However, we did meta-regression analyses on various sources including geographical distribution, age category and year of publication. These might come from age category (P = 0.002) and year of publication (P = 0.023) but not from geographic distribution (p = 0.56).

CONCLUSIONS

Intestinal parasite infections are highly prevalent and well distributed across the regional states of Ethiopia. Southern and Amhara regional states carry the highest burden. Although school-age children have higher prevalence of IPIs compared to preschool-age children, the prevalence is still unacceptably higher among preschool-age children. We observed a gradual, but significant decrease in prevalence of IPIs among preschool and school-age in Ethiopian in the last two decades with no significant difference between males and females. The prevalence in the most recent six years was around 42% compared to 71% in the late 1990s. Place of residence has no effect on the burden of IPIs among preschool and school-age in Ethiopian. Sixteen percent (16%) of preschool and school-age children had concurrent poly-parasitism infections.

LIST OF ABBREVIATIONS
IPIs, Intestinal parasite infections; MDA, mass drug administration; NGOs, non-governmental organizations; GRADE, Grading of Recommendations Assessment, Development and Evaluation; CI, confidence interval; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; STHs, soil-transmitted helminthes.

DECLARATIONS

Ethics approval and consent to participate: None applicable

Consent for publication: Not applicable.

Availability of data and materials: The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request

Competing interests: The authors declare that they have no competing interests.

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Authors’ contributions: LCH and ZM conceived the study. LCH and YA extracted the data, and independently decided for inclusion or exclusion, and in events of disagreement, ZM helped to resolve. LCH and DE performed all the statistical analyses. LCH and YA prepared manuscript with the help from DE. All authors read and approved the final manuscript.

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TABLES

Table 1 Characteristics of the 83 eligible studies of intestinal parasite infections in Ethiopia

| Author            | Study design  | Population       | Male  | Female | Study site(s)Regi | Methods      | No. sample | No. positive (%) | Quality assessment |
|-------------------|---------------|------------------|-------|--------|-------------------|--------------|------------|------------------|---------------------|
| Degar 2013        | Cross-sectional | School children | 187   | 216    | Tikur Wuha, Gojam , Amhara region | Kato-Katz    | 403        | 235 (58.3%)      | 2                   |
| Abdi 2017         | Cross-sectional | School children | 207   | 201    | Zegie Peninsula, Gojam, Amhara region | Formalin-ether | 408        | 282 (69.1%)      | 3                   |
| Abera 2014        | Cross-sectional | School children | 193   | 192    | Bahir Dar, Amhara region | Formalin-ether | 385        | 170 (44.2%)      | 3                   |
| Study | Year | Design | Setting | Sample Size | Test Methodology | HIV Prevalence | Comment |
|-------|------|--------|---------|-------------|-----------------|--------------|---------|
| Wegayehu et al. | 2013 | Cross-sectional | School children | 191 | Direct and formal ether and modified Ziehl-Neelsen | 384 | 81 (21.1%) |
| Amare | 2013 | Cross-sectional | School children | 218 | Direct, formal ether and Kato-Katz | 405 | 92 (22.7%) |
| Gelaw | 2013 | Cross-sectional | School children | 170 | Direct and formal ether | 304 | 104 (34.2%) |
| Abossie | 2014 | Cross-sectional | School children | 191 | Direct and formal ether | 400 | 324 (81.0%) |
| Matthewos | 2014 | Cross-sectional | School children | 139 | Direct, formal ether and modified Ziehl-Neelsen | 261 | 174 (66.7%) |
| Gizaw | 2018 | Cross-sectional | Preschool children | 106 | Kato-Katz | 225 | 58 (25.8%) |
| Wegayehu et al. | 2016 | Cross-sectional | Both | 154 | PCR | 312 | 48 (16.8%) |
| Yimam | 2016 | Cross-sectional | School children | 187 | Formol-ether and Kato-Katz | 403 | 235 (58.3%) |
| Hailegebriel | 2017 | Cross-sectional | School children | 177 | Formol-ether | 359 | 235 (65.5%) |
| Study | Year   | Type          | Setting          | Total 1 | Total 2 | Methodology                     | Count 1 | Count 2 | Methodology                     | Count 1 | Count 2 | Methodology                     |
|-------|--------|---------------|------------------|---------|---------|---------------------------------|---------|---------|---------------------------------|---------|---------|---------------------------------|
| Dar, Amhara region | 2018   | Cross-sectional | School children  | 196     | 195     | Formol-ether                    | 391     | 182(46.5%) | Formol-ether                    | 391     | 182(46.5%) | Formol-ether                    |
| Birbir town, Gamo Gofa, South region | 2019  | Cross-sectional | School children  | 180     | 171     | Direct and formol-ether         | 351     | 95(27.1%) | Direct and formol-ether         | 351     | 95(27.1%) | Direct and formol-ether         |
| Woreta health center, Gondar, Amhara region | 2019 | Cross-sectional | Preschool children | 152   | 158     | Direct and Kato-Katz            | 310     | 58(18.70%)  | Direct and Kato-Katz            | 310     | 58(18.70%) | Direct and Kato-Katz            |
| Mizan Aman town, Bench Maji, South region | 2015  | Cross-sectional | School children  | 228     | 232     | Direct and formol-ether and Kato-Katz | 460     | 353(76.7%) | Direct and formol-ether and Kato-Katz | 460     | 353(76.7%) | Direct and formol-ether and Kato-Katz |
| Dembiya District, Gondar, Amhara region | 2016  | Cross-sectional | Preschool children | 183   | 218     | Kato-Katz                       | 401     | 141(35.2%)  | Kato-Katz                       | 401     | 141(35.2%) | Kato-Katz                       |
| Wolaita Zone, South region | 2017  | Cross-sectional | School children  | 287     | 216     | Kato-Katz and formol-ether      | 503     | 363(72.2%) | Kato-Katz and formol-ether      | 503     | 363(72.2%) | Kato-Katz and formol-ether      |
| Maksegnit and Enfranz Towns, Gondar, Amhara region | 2016 | Cross-sectional | School children  | 255     | 295     | Kato-Katz                       | 550     | 365(66.4%) | Kato-Katz                       | 550     | 365(66.4%) | Kato-Katz                       |
| Jimma town, Oromia region | 2016  | Cross-sectional | School children  | 238     | 262     | Kato-Katz                       | 500     | 120(24%)  | Kato-Katz                       | 500     | 120(24%)  | Kato-Katz                       |
| Rural area of Bahir Dar, Amhara region | 2016  | Cross-sectional | School children  | 225     | 171     | Formol-ether                    | 396     | 327(82.6%) | Formol-ether                    | 396     | 327(82.6%) | Formol-ether                    |
| Study                        | Year     | Design          | Setting                      | Study Population | Sputum Stain Used | Acid-fast Bacilli Rate | Region       |
|------------------------------|----------|-----------------|------------------------------|------------------|-------------------|------------------------|--------------|
| Nute et al. (2018)           | 2018     | Cross-sectional | School children              | 7418             | 8037              | Ten zones of the Amhara region |             |
| Zemen et al. (2018)          | 2018     | Cross-sectional | Preschool children           | 118              | 118               | Debre Birhan hospital, North Shewa, Amhara region |             |
| Gebretsadik et al. (2018)    | 2018     | Cross-sectional | Preschool children           | 133              | 99                | Dessie referral Hospital, Amhara region |             |
| Mulatu et al. (2015)         | 2015     | Cross-sectional | Preschool children           | 81               | 77                | Adare Hospital and Millennium Health Centre, Hawassa, South region |             |
| Bekana et al. (2019)         | 2019     | Cross-sectional | School children              | 172              | 145               | Guma and YachiYisa in Gomma, Jimma, Oromia region |             |
| Diro et al. (2015)           | 2015     | Prospective cohort | Both                        | 85               | 37                | University of Gondar and Kahsay Abera Humera hospitals, Amhara region |             |
| Birhanu et al. (2018)        | 2018     | Cross-sectional | School children              | 194              | 228               | Direct, formol-ether and Kato-Katz |             |
| Fentie et al. (2013)         | 2013     | Cross-sectional | School children              | 361              | 159               | Direct, formol-ether and Kato-Katz |             |
| Authors                  | Study Type       | Setting                              | Sample Size | Positive Cases | Methodology          | Positive Rate  | Year |
|--------------------------|------------------|--------------------------------------|-------------|----------------|----------------------|----------------|------|
| Alemjoy                  | Cross-sectional  | Preschool children                   | NA          | NA             | Formol-ether         | 212            | 2017 |
|                         |                  |                                       |             |                |                      | 138            | (65.1%)|
| Desalegn                 | Cross-sectional  | School children                      | 271         | 315            | Jimma Town, Jimma, Oromia | 586            | 2014 |
|                         |                  |                                       |             |                | Direct and formol-ether | 134            | (33.9%)|
| Gebrehiwot               | Cross-sectional  | Preschool children                   | 195         | 179            | Wonji Shoa Sugar, Oromia region | 374            | 2013 |
|                         |                  |                                       |             |                | Kato-Katz            | 91(24.3%)      |      |
| Leta                     | Cross-sectional  | School children                      | NA          | NA             | 53 schools of Amhara region | 2,650          | 2018 |
|                         |                  |                                       |             |                | Kato-Katz            | 354            | (13.4%)|
| King                     | Cross-sectional  | Both                                 | 1130        | 1228           | South Gondar, Amhara region | 2,338          | 2013 |
|                         |                  |                                       |             |                | Formol-ether         | 1471(63%)      |      |
| Mekonnen                 | Clinical trial   | School children                      | NA          | NA             | 14 schools of Jimma town, Oromia region | 840            | 2013 |
|                         |                  |                                       |             |                | Kato-Katz            | 437(52%)       |      |
| Mahmod                   | Clinical trial   | School children                      | 152         | 217            | Mekele University, Tigray region | 369            | 2015 |
|                         |                  |                                       |             |                | Direct, formol-ether and Kato-Katz | 267(73%)      |      |
| Mahmod                   | Cross-sectional  | School children                      | 288         | 312            | Mekele, Tigray       | 600            | 2013 |
|                         |                  |                                       |             |                | Direct, formol-ether and Kato-Katz | 421(72%)      |      |
| Tefera                   | Cross-sectional  | School children                      | 282         | 433            | Mendera, Jimma, Oromia region | 715            | 2017 |
|                         |                  |                                       |             |                | McMast er            | 346(48.4%)     |      |
| Tefera                   | Cross-sectional  | School children                      | 364         | 280            | Babble town, Harrerg e, Oromia region | 644            | 2015 |
|                         |                  |                                       |             |                | McMast er            | 89(13.8%)      |      |
| Study                  | Type          | Location                      | Sample Size | Results        | Method          | Region            | Other Details       |
|-----------------------|---------------|-------------------------------|-------------|----------------|-----------------|-------------------|---------------------|
| Nguyen 2012[24]       | Cross-sectional | Angolel Woreda, Amhara region | 341         | 323            | Formal-ether    | Amhara region     |                     |
| Hailu 2018[96]        | Cross-sectional | Bahir Dar, Amhara region      | 186         | 223            | Formol-ether    | Amhara region     |                     |
| Beyene 2014[21]       | Cross-sectional | Jimma Health Center, Jimma, Oromia region | 114         | 146            | Direct and formol-ether |                |                     |
| Alemu 2011[34]        | Cross-sectional | Zarima town, Gondar, Amhara region | 157         | 162            | Direct and Kato-Katz | Amhara region     |                     |
| Alemayehu 2015[97]    | Cross-sectional | Demba Girara, Woliata, South region | 201         | 183            | Direct and Kato-Katz |                |                     |
| Ali 1999[98]          | Cross-sectional | Asenda Town, Jimma, Oromia region | 161         | 121            | Direct and Kato-thick |                |                     |
| Tulu 2016[71]         | Cross-sectional | Birbir, Bale Zone, Oromia region | 251         | 241            | Direct and formol-ether |                |                     |
| Unasho 2013[76]       | Cross-sectional | Gedeo, Woliata and Kamba ta and Amaro, South region | 189         | 217            | Direct          | South region      |                     |
| Belyhu 2010[55]       | Follow-up cohort | Butajira town, South region | NA          | NA             | Formol-ether    |                |                     |
| Tulu 2014[44]         | Cross-sectional | Delo-Mena, Bale Zone, Oromia region | 172         | 168            | Direct           |                |                     |
| Erosie 2002[46]       | Cross-sectional | Boloso Sorie, South region | NA          | NA             | Formol-ether    |                |                     |
| Tadess                | Cross          | Babile                        | 271         | 144            | Formal          |                |                     |
| Author       | Year | Study Type   | Setting                        | Pathology Method         | AFB Count | Percentage | Year | AFB Count | Percentage |
|--------------|------|--------------|--------------------------------|--------------------------|-----------|------------|------|-----------|------------|
| Adamu        | 2005 | Cross sectional | Preschool children | Direct, formal-ether and Modified Ziehl-Neelsen | 149 | 147 | Police Hospital, Armed Forces, General Hospital, and Tikur Anbessa Hospital, Addis Ababa | 296 | 69(23.3%) | 0 |
| Jemane       | 1999 | Cross sectional | School children | Kato-Katz and formal-ether | 439 | 439 | Gondar town, Gondar, Amhara region | 878 | 437(49.7%) | 0 |
| Dejenie      | 2009 | Cross sectional | School children | Kato-Katz and formal-ether | 1012 | 998 | Central Tigray, Tigray region | 2000 | 571(28.6%) | 0 |
| Dejenie      | 2010 | Cross sectional | School children | Kato-Katz and formal-ether | 319 | 303 | Tigray, Tigray region | 622 | 165(26.5%) | 0 |
| Nyantekyi    | 2010 | Cross sectional | Preschool children | Kato-Katz and formal-ether | 140 | 148 | Wondo Genet, South region | 288 | 245(85.1%) | 1 |
| Legesse       | 2010 | Cross sectional | School children | Kato-Katz and formal-ether | 167 | 214 | Adama town, Oromia region | 381 | 263(69%) | 0 |
| Terefe       | 2011 | Cross sectional | School children | Kato-Katz and formal-ether | 218 | 201 | Bushulo, Hawassa, South region | 419 | 282(67.3%) | 1 |
| Assefa       | 2013 | Cross sectional | School children | Kato-Katz and formal-ether | 267 | 190 | Suburbs of Mekelle city, Tigray region | 457 | 109(23.9%) | 0 |
| Debalko      | 2013 | Cross sectional | School children | McMaster | 161 | 205 | Jimma town, Oromia region | 366 | 166(45.4%) | 1 |
| Dejene       | 2008 | Cross sectional | School children | Formal-ether | 481 | 319 | Hintallo-ether | 800 | 285(35.6%) | 0 |
| Study | Design | Group 1 | Group 2 | Region 1 | Region 2 | Method 1 | Method 2 | Outcome 1 |
|-------|--------|---------|---------|---------|---------|----------|----------|-----------|
| Fekadu 2008 | Cross-sectional | School children | 63 | 37 | Wejera town, Jimma, Oromia region | Harada-Mori (Test tube culture) | 100 | 66(66%) |
| Haileamlak 2005 | Cross-sectional | Preschool children | 487 | 437 | Jimma Zone, Jimma, Oromia region | Direct and formal-ether | 924 | 530(57.4%) |
| Jemaneh 2001 | Cross-sectional | School children | 282 | 405 | Chilga, Gondar Zone, Amhara region | Kato-Katz | 687 | 470(68.4%) |
| Firdu 2014 | Case-control | Both | 135 | 95 | Yirgalem Hospital, South region | Direct formol-ether and modified Ziehl-Neelsen | 230 | 74(32.2%) |
| Wale 2014 | Cross-sectional | School children | 206 | 196 | Lumame town, Amhara region | Direct and formal ether | 402 | 219(54.5%) |
| Teklemariam 2014 | Cross-sectional | School children | 252 | 228 | Enderta, Tigray region | Formalin-ether | 480 | 199(41.5%) |
| Ayalew 2011 | Cross-sectional | School children | 358 | 346 | Delgi, Gondar, Amhara region | Direct and formal-ether | 704 | 562(79.8%) |
| Merid 2001 | Cross-sectional | School children | NA | NA | Lake Hawassa, South region | Direct and formal-Ether | 150 | 139(92.7%) |
| Assefa 1998 | Cross-sectional | School children | 479 | 219 | Wollo, Amhara region | Formal-ether | 698 | 304(43.3%) |
| Roma 1997 | Cross-sectional | School children | 352 | 168 | Wondo-Genet, South region | Formol-ether | 520 | 465(89.4%) |
| Abera 2013 | Cross-sectional | School children | 397 | 381 | Bahir Dar special zones, Kato-Katz and formal-ether | | 772 | 401(51.5%) |
| Study | Type | Location | Group | Sample Size | Method | Test | Result |
|-------|------|----------|-------|-------------|--------|------|--------|
| Kidane 2014[57] | Cross sectional | School children | 177 | 207 | Wukro wered, Tigray region | Direct | 384 | 233(60.7%) | 0 |
| Alamir 2013[29] | Cross sectional | School children | 192 | 207 | Dagi, Amhara region | Direct and formal-ether | 399 | 311(77.9%) | 0 |
| Kabeta 2017[103] | Cross sectional | Preschool children | NA | NA | Hawassa Zuria, South region | Direct smear and formal-ether | 587 | 301(51.3%) | 1 |
| Shemb e 2015[104] | Cross sectional | Preschool children | 165 | 212 | Butajira, South region | McMasters | 377 | 104(27.6%) | 3 |
| Tadege 2017[105] | Cross sectional | School children | 235 | 139 | Fincha wa and Tullo, South region | Formal-ether | 374 | 254(67.9%) | 3 |
| Andual em 2014[106] | Cross sectional | School children | 168 | 190 | Motta, Gojam, Amhara region | Direct and formal-ether | 358 | 245(68.4%) | 0 |
| Reji 2011[51] | Cross sectional | School children | NA | NA | Adama town, Oromia region | Kato-Katz | 358 | 127(35.5%) | 1 |
| Alemu 2014[70] | Cross sectional | School children | 211 | 194 | Umolante, Gamo Gofa, South region | Kato-Katz | 405 | 109(26.9%) | 0 |
| Samuel 2015[108] | Cross sectional | School children | NA | NA | Ambo town, Oromia region | Formal-ether | 375 | 47(12.6%) | 3 |
| Teshale 2018[107] | Cross sectional | School children | 240 | 170 | Medebay Zana, Tiray region | Kato-katz | 410 | 52(12.7%) | 1 |
| Tekeste 2013[66] | Cross sectional | School children | 170 | 156 | Gorgora, Amhara region | Kato-katz | 326 | 110(36.8%) | 2 |

**Abbreviations:** NA, not available; PCR, Polymerase chain reaction
Figures
Flow diagram showing the selection process
Figure 2

Begg’s funnel plot and Egger test for heterogeneity of intestinal parasite infection:
Figure 3

Regional distribution of intestinal parasite infections in Ethiopian children from 1997-2019
Figure 4

Forest plot showing the geographic distribution of intestinal parasite infections in
Figure 5

Forest plot showing age related distribution of intestinal parasite infections in Ethiopia.
Figure 6

Forest plot showing trend of intestinal parasite infections in Ethiopia children
Figure 7

Meta regression result of A. the geographic distribution B. the distribution by age

Supplementary Files

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