A Systematic Review and Meta-analysis of Soil Transmitted Helminths Infections Among Preschool and School-age Children in Ethiopia: Evaluation of Neglected Tropical Diseases (NTDS) Elimination Program by 2020

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Abstract

**Background:** Comprehensive nationwide on prevalence, geographic distribution of different species and time trends of soil-transmitted helminths (STHs) are lacking. Therefore, the aim of this study was to provide a summary and location of the available data on STHs infection among preschool and school-age children in Ethiopia.

**Methods:** The search were carried out in Medline via PubMed, Scopus, Science Direct, Web of Science and Google Scholar on data published between 1995 to February 2020 for studies describing rate of STHs infection among preschool and school-age in Ethiopian. We followed Patient, intervention, Comparison and Outcome (PICO) approach to identify the studies. Endnote citation manager software version X9 for Windows was utilized to collect and organize search outcomes (into relevant and irrelevant studies) and for removal duplicate articles. We conducted meta-regression to understand the trends and the source of heterogeneity and pooled the prevalence using ‘metaprop’ command using STATA software version 14.

**Results:** A total of 29,311 of the 61,690 children examined during the period under review were infected with one or more species of intestinal parasites yielding an overall prevalence of 48 % (95%CI: 43-53%). The overall pooled estimate of STHs was 33% (95% CI: 28-38%). The prevalence was 44% (95%CI : 31% - 58%) in SNNPR, 34%((95%CI : 28% - 41%) in Amhara region, 31% (95%CI : 19% - 43%) in Oromia region and 10% (95%CI : 7% - 12%) in Tigray region. Soil-transmitted helminths infection rate has been decreasing from 44% (95% CI:30-57%) pre-Mass Drug Administration (MDA) era (1997-2012) to 30% (95% CI:25-34%) post-MDA (2013-2020), although statistically not significant (p = 0.45). *A. lumbricoides* was the predominant species with a prevalence of 17%.

**Conclusion:** Southern Nations Nationalities and Peoples Region, Amhara and Oromia regions carry the highest burden and are categorized to Moderate Risk Zones (MRZ) and therefore, requiring mass drug administration (MDA) once annually with Albendazole or Mebendazole. Prevalence of STHs decreased after MDA compared to before MDA, but the decline was not statistically significant. *A. lumbricoides* was the predominant species of STHs among preschool and school-age children in Ethiopia.

**Background**

Soil transmitted helminths (STHs) infections have been among the most widely distributed infections in the resources limited countries. Globally, more than 4.5 billion people are at risk of infection with nearly 2 billion are infected with STHs [1, 2]. In contrast to other infectious diseases, infection due to STHs such as *Ascaris lumbricoides*, hookworm species *and Trichuris trichiura* do not usually cause significant mortality rates; instead adapted to chronic illness and extended morbidity affecting poor people [3–6]

Transmissions of the STHs are mainly by eggs or larvae that are passed with feces of infected person or hatched in soil after defecation. Adult worms residing in the gut of infected person produce thousands of eggs every day, which may contaminate environments or foods that lack adequate sanitation [7]. Additionally, climatic conditions of tropical and sub-tropical countries are suitable for the survival of STH eggs and larvae hatching and embryonation in warm temperature and adequate moisture soil [8]. Consequently, the complication of STH may cause gut blood losses, malabsorption of nutrients, loss of appetites and anemia due to loss of iron and other important protein [9]. For instance, the infections outcome on the children results in serious problems such as anemia, growth retardation, impaired cognitive developments, school absenteeism and disability adjusted life years lost [10, 11].

World Health Organization (WHO) has published a comprehensive road map data in 2012 to combat Neglected tropical diseases (NTDs) by 2020. Mass Drug Administration (MDA) approach was also designed to undertake 75% coverage in all of known endemic countries for STHs. The ideas of WHO was strengthen by the London declaration to control or eliminate other 10 NTDs in addition to the STHs [12, 13]. Recently, following WHO strategic plan, Ethiopia has launched a nationwide MDA to control STHs, which targets 17 million children within the age range of 5–14 years old. Ethiopian Ministry of health and WHO started school children deworming in 2013 and 2014 about 6.8 million and 7.8 million school-age children, respectively. Even prior to the dewarming program, the ministry of health has undertaken some other measures to control poverty related diseases including STHs among the population at risk, particularly school-age children. For instance, implementation of health extension program focusing on creating awareness on latrine construction and utilization and keeping personal and environmental hygiene among the community is one priority program since 2003/2004. However, current individual reports indicated that the prevalence of STHs in Ethiopia is not declining. Evidently, a large scale study conducted in Amhara regional state showed that the prevalence of STHs was 36.4% [14]. Another study in Jimma town showed that the prevalence of STHs among school-age children was 49.0% [15]. A similar study also reported that the prevalence of STHs was 47% in rural community of Ethiopia [16]. Nevertheless, numerous fragmented studies have been carried out on assessing
the prevalence of STHs among preschool and school-age children in Ethiopia, but a comprehensive nationwide data on the prevalence, geographic distribution of different species and time trends of STHs are lacking. Therefore, the aim of this study was to provide a summary on prevalence, geographical location and time trends of STHs among preschool and school-age children to measure the impact of the ongoing control and preventive measures in the country. In addition, such effort help the government and other concerned bodies to focus on specific areas of high prevalence for further preventive measures such as chemotherapy and improved sanitation practices.

Methods

This Systematic Reviews and Meta-analyses was carried out following the PRISMA guideline (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)[17]. We used the PRISMA guideline for the inclusion of potentially related studies to the outcome of interest. The outcome of interest was the prevalence of soil-transmitted helminths (STHs) among preschool and school-age children in Ethiopia.

Search Strategy

The search were carried out in Medline via PubMed, Scopus, Science Direct, Web of Science and Google Scholar using searching terms such as "intestinal helminths", "intestinal parasites", "soil transmitted helminths", "STHs", "Strongyloides stercoralis", "Ascaris lumbricoides", "Trichuris trichiura", "Hookworms", "preschool-age", "school-age", "Ethiopia". These key terms were combined using "AND" and "OR" Boolean operators. Medical Subject Headings (MeSH terms) was used to search relevant original articles in PubMed. Searching was carried out on articles published between 1995 to February 2020 and limited to English language and human studies. 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. Endnote citation manager software version X9 for Windows was utilized to collect and organize search outcomes (into relevant and irrelevant studies) and for removal duplicate articles. We followed PICO approach to identify the relevant articles:

- Population (P): School-age children
- Exposure (E): Presence of soil-transmitted helminths
- Comparison (C): Preschool-age children
- Outcome (O): Prevalence of soil transmitted helminths.

Prevalence was calculated as the number of subjects positive for STHs in the study divided by the total number of participants in a study multiplied by 100.

Inclusion And Exclusion Criteria

We included observational studies or controlled clinical trials conducted between 1997 to February 2020 which documented the baseline prevalence or incidence of STHs and studies published in English language targeting both pre-school (< 5 years) and school-age children (≥ 5 years). We excluded case reports, case series, studies that compared the sensitivity and specificity of different methods for diagnosis of STHs and studies not reported either prevalence or incidence as outcome of interest.

Data Abstraction And Quality Assessment

Following preliminary assessment and downloading of the abstracts by two authors, they were assessed for agreement with the inclusion criteria. Irrelevant articles (articles which were out of the scope of the study) were excluded after assessment of the abstracts unless it was unclear to classify articles into irrelevant based on abstracts, where we downloaded the full-text for further clarity. Once articles deemed to be relevant, the full-text of the articles were downloaded for further detailed review. We extracted information on name of the first author and year of publication, study design, gender, region of study, laboratory method identification of the parasites, total sample size, the number of positives for intestinal paraistes in general, number of positive for STHs in particular, and quality score for quality assessment. The Grading of Recommendation Assessment, development and Evaluation (GRADE)
approach was used to assess the overall quality of evidence [18]. 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. We regarded publications with a total score of 3–4 points to be of 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. Statistical heterogeneity among studies was expressed as the Cochrane’s Q test and $I^2$, where a $P < 0.05$ and $I^2$ values of 0, 25, 50 and 75% were considered as no, low, moderate and high heterogeneities, respectively. Because we expected geographical variation and socio-economic contexts might differ radically across these studies, subgroup analysis based on geography of region, age children included and year of publication. In addition to visual inspection for symmetry of the plot, we also used Begg’s Funnel plot and Egger’s regression test for quantitative evaluation of the possibility of publication bias. Meta-regression analysis was employed to identify the source of heterogeneity using regional states, age of children, publication years and study design as covariates. All reported P values were 2-sided and were statistical significant if $P < 0.05$.

Results

Literature searches and selection

Our initial search of electronic databases such as Medline via PubMed, Scopus, Science direct, Web of Sciences and Google scholar yielded 953 articles and 3 articles manually from which 213 records remained after removing duplications. Upon screening the articles, 123 articles were further excluded; 112 were irrelevant because they were not specifically about preschool or school-age children, 6 studies were about sensitivity and specificity of diagnosis of STHs, and 5 articles were not about human. Upon further assessment for eligibility, 2 studies were excluded being review articles. Finally, 88 [6, 14, 16, 19–110] published studies between 1997 and February 2020 fulfilling the inclusion criteria were included in the final analyses [Figure 1]. The sample size of the included studies ranged from 100 [20] to 15,455 [14]. A total of 61,690 children with age of < 5 years (n = 5577) and ≥ 5 years (n = 55731) or mix of both (n = 382) were recruited in the studies. Fifty two percent (52%) of the study participants were male. Majority (83) of the studies were cross sectional. Seventy three studies were about STHs in school-age children, 13 were about preschool-age and the rest were studies involved both preschool and school-age children. Thirty five and twenty four studies used Kato-katz or in combination with other tools and formalin-ether concentration plus direct microscopic method for screening stools, respectively. Formalin-ether concentration techniques in 19 studies, direct wet mount method in 5 studies, McMaster in 4 studies and Harada Mori (Test tube culture) technique in one study utilized as screening of stools. According to our quality assessment criteria, 43 publications were of high quality with a score of 3, 11 had a score of 2 indicating moderate quality and the remaining 34 were of low quality with a score of zero or one [Table 1].
Table 1
Characteristics of the eligible studies on STH infections in Ethiopia

| Name of first author and year | Study design | Population | Male | Female | Region | Laboratory method | No. sample | Cases for IPIs | Quality score |
|------------------------------|--------------|------------|------|--------|--------|-------------------|------------|---------------|---------------|
| Degarege 2013[34]            | Cross-sectional | School children | 187  | 216   | Amhara | KATO             | 403        | 255           | 2             |
| Abdi 2017[73]                | cross-sectional | School children | 207  | 201   | Amhara | FEC              | 408        | 282           | 3             |
| Abera 2014[74]               | Cross-sectional | School children | 193  | 192   | Amhara | FEC              | 385        | 357           | 3             |
| Amare 2013[26]               | Cross-sectional | School children | 218  | 187   | Amhara | KTO &FEC         | 405        | 92            | 3             |
| Gelaw 2013[41]               | cross-sectional | School children | 170  | 134   | Amhara | DWM&FEC          | 304        | 104           | 3             |
| Abossie 2014[76]             | Cross-sectional | School children | 191  | 209   | SNNPR  | DWM&FEC          | 400        | 324           | 3             |
| Mathewos 2014[53]            | Cross-sectional | School children | 139  | 122   | Amhara | DWM&MZN          | 261        | 174           | 2             |
| Gizaw 2018[108]              | Cross-sectional | Preschool children | 106  | 119  | Amhara | KATO             | 225        | 58            | 3             |
| Yimam 2016[72]               | Cross-sectional | School children | 187  | 216   | Amhara | KTO&FEC          | 403        | 235           | 3             |
| Hailegebriel 2017[77]        | Cross-sectional | School children | 177  | 182   | Amhara | FEC              | 359        | 235           | 3             |
| Alemu 2018[78]               | Cross-sectional | School children | 196  | 195   | SNNPR  | FCE              | 391        | 182           | 2             |
| Alemu 2019[80]               | Cross-sectional | School children | 180  | 171   | SNNPR  | DWM&FEC          | 351        | 95            | 3             |
| Mekonnen 2019[109]           | Cross-sectional | Preschool children | 152  | 158   | Amhara | DWM&KATO         | 310        | 58            | 3             |
| Jejaw 2015[36]               | Cross-sectional | School children | 228  | 232   | SNNPR  | DWM,FEC&KATO    | 460        | 353           | 3             |
| Alemu 2016[79]               | Cross-sectional | Preschool children | 183  | 218   | Amhara | KATO             | 401        | 141           | 3             |
| Alemayehu 2017[54]           | Cross-sectional | School children | 287  | 216   | SNNPR  | KATO&FEC        | 503        | 363           | 3             |
| Gashaw 2015[57]              | Cross-sectional | School children | 255  | 295   | Amhara | KATO             | 550        | 365           | 3             |
| Amor 2016[82]                | Cross-sectional | School children | 225  | 171   | Amhara | FEC              | 396        | 327           | 3             |
| Nute 2018[14]                | Cross-sectional | School children | 7418 | 8037  | Amhara | FEC              | 15455      | 5626          | 3             |
| Zemene 2018[68]              | Cross-sectional | Preschool children | 118  | 118  | Amhara | DWM&FEC         | 247        | 43            | 1             |
| Mulatu 2015[24]              | Cross-sectional | Preschool | 81   | 77    | SNNPR  | DWM,FEC&MZN     | 158        | 224           | 3             |

DWM = direct wet mount; FEC = formal-ether; KATO = kato-katz; NNNPR = Southern nations nationalities and peoples region; IPIs = intestinal parasitic infections; STHs = soil transmitted helminths; NA = not available.
| Name of first author and year | Study design | Population | Male | Female | Region           | Laboratory method       | No. sample | Cases for IPIs | Quality score |
|-------------------------------|--------------|------------|------|--------|------------------|------------------------|------------|----------------|---------------|
| Bekana 2019[84]               | Cross-sectional | School children | 172  | 145    | Oromia           | KATO&FEC               | 317        | 130            | 3             |
| Diro 2015[85]                 | Prospective cohort | Both | 85   | 37     | Amhara           | DWM,FEC&KATO           | 122        | 371            | 1             |
| Birhanu 2018[86]             | Cross-sectional | School children | 194  | 228    | Benishangul-Gumuz | DWM                    | 422        | 138            | 1             |
| Fentie 2013[22]              | Cross-sectional | School children | 361  | 159    | Amhara           | KATO&FEC               | 520        | 134            | 3             |
| Aiemjoy 2017[63]             | Cross-sectional | Preschool children | NA   | NA     | Amhara           | FEC                    | 212        | 354            | 2             |
| Dessalegn 2014[21]           | Cross-sectional | School children | 271  | 315    | Oromia           | DWM&FEC                | 586        | 91             | 3             |
| Gebrehiwot 2014[110]         | Cross-sectional | Preschool children | 195  | 179    | Oromia           | KATO                   | 374        | 1471           | 2             |
| Leta 2018[87]                | Cross-sectional | School children | NA   | NA     | Amhara           | KATO                   | 2,650      | 437            | 3             |
| King 2013[37]                | Cross-sectional | Both | 1130 | 1228   | Amhara           | FEC                    | 2,338      | 267            | 3             |
| Mekonnen 2013[6]             | Clinical trial  | School children | NA   | NA     | Oromia           | KATO                   | 840        | 421            | 3             |
| Mahmud 2015[44]              | Clinical trial  | School children | 152  | 217    | Tigray           | DWM,FEC&KATO           | 369        | 326            | 3             |
| Mahmud 2013[43]              | Cross-sectional | School children | 288  | 312    | Tigray           | DWM,FEC&KATO           | 600        | 89             | 3             |
| Tefera 2017[70]              | Cross-sectional | School children | 282  | 433    | Oromia           | McMaster               | 715        | 202            | 2             |
| Tefera 2015[88]              | Cross-sectional | School children | 364  | 280    | Oromia           | McMaster               | 644        | 237            | 2             |
| Nguyen 2012[31]              | Cross-sectional | School children | 341  | 323    | Amhara           | FEC                    | 664        | 129            | 3             |
| Hailu 2018[111]              | Cross-sectional | School children | 186  | 223    | Amhara           | Richie's               | 409        | 263            | 2             |
| Beyene 2014[28]              | Cross-sectional | School children | 114  | 146    | Oromia           | DWM&FEC                | 260        | 328            | 3             |
| Alemu 2011[25]               | Cross-sectional | School children | 157  | 162    | Amhara           | KATO&DWM               | 319        | 243            | 3             |
| Alemayehu 2015[90]           | Cross-sectional | School children | 201  | 183    | SNNPR            | KATO&DWM               | 384        | 131            | 1             |
| Ali 1999[91]                 | Cross-sectional | School children | 161  | 121    | Oromia           | KATO&DWM               | 282        | 170            | 0             |
| Tulu 2016[65]                | Cross-sectional | School children | 251  | 241    | Oromia           | DWM&FEC                | 492        | 44             | 0             |
| Unasho 2013[71]              | Cross-sectional | School children | 189  | 217    | SNNPR            | DWM                    | 406        | 89             | 0             |

DWM = direct wet mount; FEC = formal-ether; KATO = kato-katz; SNNPR = Southern nations nationalities and peoples region, IPIs = intestinal parasitic infections; STHs = soil transmitted helminths; NA = not available.
| Name of first author and year | Study design | Population | Male | Female | Region  | Laboratory method | No. sample | Cases for IPIs | Quality score |
|------------------------------|--------------|------------|------|--------|---------|-------------------|------------|---------------|--------------|
| Belyhun 2010[49] | Follow up cohort | Preschool children | NA   | NA     | SNNPR   | FEC               | 905        | 292           | 3            |
| Tulu 2014[38] | Cross sectional | School children | 172  | 168    | SNNPR   | DWM&FEC            | 340        | 113           | 1            |
| Erosie 2002[40] | Cross sectional | School children | NA   | NA     | SNNPR   | FEC               | 421        | 69            | 1            |
| Tadesse 2005[33] | Cross sectional | School children | 271  | 144    | Oromia  | FEC               | 415        | 437           | 0            |
| Adamu 2005[48] | Cross sectional | Preschool children | 149  | 147    | Addis Ababa | DWM,FEC&MZN  | 296        | 571           | 0            |
| Jemaneh 1999[92] | Cross sectional | School children | 439  | 439    | Amhara  | KATO              | 878        | 165           | 0            |
| Dejenie 2009[56] | Cross sectional | School children | 1012 | 998    | Tigray  | DWM               | 2000       | 245           | 0            |
| Dejenie 2010[66] | Cross sectional | School children | 319  | 303    | Tigray  | KATO              | 622        | 263           | 0            |
| Nyantekyi 2010[32] | Cross sectional | Preschool children | 140  | 148    | SNNPR   | KATO&FEC          | 288        | 282           | 1            |
| Legesse 2010[52] | Cross sectional | School children | 167  | 214    | Oromia  | KATO&FEC          | 381        | 166           | 0            |
| Terefe 2011[61] | Cross sectional | School children | 218  | 201    | SNNPR   | KATO              | 419        | 285           | 1            |
| Debalke 2013[93] | Cross sectional | School children | 161  | 205    | Oromia  | McMaster          | 366        | 66            | 1            |
| Dejene 2008[94] | Cross sectional | School children | 481  | 319    | Tigray  | FEC               | 800        | 530           | 0            |
| Fekadu 2008[19] | Cross sectional | School children | 63   | 37     | Oromia  | Harada-Mori (Test tube culture) | 100 | 470 | 0 |
| Haileamlak 2005[23] | Cross sectional | Preschool children | 487  | 437    | Oromia  | DWM&FEC          | 924        | 74            | 1            |
| Jemaneh 2001[42] | Cross sectional | School children | 282  | 405    | Amhara  | KATO              | 687        | 219           | 1            |
| Firdu 2014[69] | Case-control | Both          | 135  | 95     | SNNPR   | DWM,FEC&MZN      | 230        | 199           | 1            |
| Wale 2014[62] | Cross sectional | School children | 206  | 196    | Amhara  | DWM&FEC          | 402        | 562           | 1            |
| Teklemariam 2014[67] | Cross sectional | School children | 252  | 228    | Tigray  | FEC               | 480        | 139           | 0            |
| Ayalew 2011[27] | Cross sectional | School children | 358  | 346    | Amhara  | DWM&FEC          | 704        | 304           | 2            |
| Merid 2001[30] | Cross sectional | School children | NA   | NA     | SNNPR   | DWM&FEC          | 150        | 465           | 0            |
| Assefa 1998[112] | Cross sectional | School children | 479  | 219    | Amhara  | FEC               | 698        | 401           | 0            |

DWM = direct wet mount; FEC = formal-ether; KATO = kato-katz; NNNPR = Southern nations nationalities and peoples region, IPIs = intestinal parasitic infections; STHs = soil transmitted helminths; NA = not available.
| Name of first author and year | Study design | Population | Male | Female | Region | Laboratory method | No. sample | Cases for IPIs | Quality score |
|-------------------------------|--------------|------------|------|--------|--------|-------------------|------------|---------------|--------------|
| Roma 1997[46]                | Cross sectional | School children | 352  | 168   | SNNPR  | FEC               | 520        | 233           | 1            |
| Abera 2013[95]               | cross sectional | School children | 397  | 381   | Amhara | KATO&FEC          | 772        | 311           | 3            |
| Kidane 2014[113]             | Cross sectional | School children | 177  | 207   | Tigray | DWM               | 384        | 301           | 0            |
| Alamir 2013[20]              | Cross sectional | School children | 192  | 207   | Amhara | DWM&FEC           | 399        | 104           | 0            |
| Kabeta 2017[96]              | Cross sectional | Preschool children | NA   | NA    | SNNPR  | DWM&FEC           | 587        | 254           | 1            |
| Shumbej 2015[97]             | Cross sectional | Preschool children | 165  | 212   | SNNPR  | McMaster          | 377        | 245           | 3            |
| Tadege 2017[98]              | Cross sectional | School children | 235  | 139   | SNNPR  | FEC               | 374        | 127           | 3            |
| Andualem 2014[99]            | Cross sectional | School children | 168  | 190   | Amhara | DWM&FEC           | 358        | 59            | 0            |
| Reji 2011[45]                | Cross sectional | School children | NA   | NA    | Oromia | KATO              | 358        | 52            | 1            |
| Alemu 2014[64]               | Cross sectional | School children | 211  | 194   | SNNPR  | KATO              | 405        | 110           | 0            |
| Samuel 2015[114]             | Cross sectional | School children | NA   | NA    | Oromia | FEC               | 375        | 42            | 3            |
| Teshale 2018[100]            | Cross sectional | School children | 240  | 170   | Tigray | KATO              | 410        | 58            | 1            |
| Tekeste 2013[60]             | Cross sectional | School children | 170  | 156   | Amhara | KATO              | 326        | 109           | 2            |
| Sitotaw 2019[60]             | Cross sectional | School children | 216  | 190   | Amhara | DWM&FEC           | 406        | 235           | 3            |
| Elfu 2018[101]               | Cross sectional | School children | 1129 | 1261  | Amhara | DWM&FEC           | 2390       | 684           | 3            |
| Molla 2018[104]              | Cross sectional | School children | 245  | 198   | SNNPR  | KATO              | 443        | 239           | 3            |
| Weldesenbet 2019[107]        | Cross sectional | School children | 349  | 251   | SNNPR  | KATO              | 600        | 57            | 3            |
| Eyamo 2019[102]              | Cross sectional | School children | 199  | 185   | SNNPR  | DWM               | 384        | 260           | 3            |
| Tadesse 2020[106]            | Cross sectional | School children | 204  | 213   | Oromia | DWM&FEC           | 422        | 131           | 2            |
| Gadisa 2019[16]              | Cross sectional | Preschool children | 242  | 319   | Oromia | DWM&FEC           | 561        | 216           | 3            |
| Zenu[110]                    | Cross sectional | School children | 284  | 28    | Oromia | DWM&FEC           | 312        | 208           | 3            |
| Shumbej[109]                 | Cross sectional | School children | 350  | 247   | SNNPR  | KATO              | 597        | 141           | 3            |

DWM = direct wet mount; FEC = formal-ether; KATO = kato-katz; SNNPR = Southern nations nationalities and peoples region, IPIs = intestinal parasitic infections; STHs = soil transmitted helminths; NA = not available.
Pooled Prevalence Estimate Of Intestinal Parasites And Heterogeneity

Eighty studies (88) studies consisting of 61,690 preschool and school-age children reported the proportion of intestinal parasitic infections. Out of these, 29,311 children were infected with one or more species of intestinal parasites giving the pooled prevalence estimate of 48% (95% CI: 43–53%) with considerable heterogeneity ($\chi^2 = 17303.64, P < 0.001; I^2 = 99.50\%$). The prevalence of intestinal parasitic infection was 53% (95% CI: 38–67%), 50% (95% CI: 44–57%), 45% (95% CI: 35–54%) and 43% (95% CI: 29–58%) in Southern Nations Nationalities and Peoples Region (SNNPR), Amhara, Oromia, and Tigray regions, respectively (Fig. 2). We also did subgroup analysis to see the influence of study design on prevalence. Interestingly enough, the prevalence was 48% (95% CI: 43–53%) for cross-sectional study design and therefore, the inclusion of other study designs has no influence on the overall rate of infection (not shown).

Overall Prevalence Estimate Of Soil-transmitted Helminthes (STHs) And Heterogeneity

Soil-transmitted helminths detected in the studies were *Ascaris lumbricoides*, Hookworms, *Trichuris trichiura* and *Strongyloides stercoralis*. A total of 19,678 of the 61,690 children examined during the period under review were infected with one or more species of STHs yielding an overall prevalence of 33% (95% CI: 28–38%) with substantial heterogeneity ($\chi^2 = 30360.02, P < 0.001; I^2 = 99.71\%$ (Fig. 3). The asymmetry of funnel plot visual inspection (Fig. 4) showed that the presence of publication bias which was statistically confirmed by Egger’s test ($\beta = 16.7, [95\% CI: 10.7–22.5], p < 0.001$ and Begg’s test $p < 0.001$). We did meta-regression analyses to search for the sources of heterogeneity. A univariate meta-regression between prevalence of STHs and age of children showed statistically significant correlation ($P = 0.003$, Fig. 5). However, year of publication, ($P = 0.076$), regional states ($p = 0.70$) and study design ($p = 0.23$) did not show a statistically significant correlation as shown in Table 2.

| Variables          | $\beta$-Coefficient | 95% CI         | p-values |
|--------------------|---------------------|----------------|----------|
| Regional states    | -0.03               | -0.18 to 0.12  | 0.70     |
| Year of publication| -0.04               | -0.004 to 0.08 | 0.076    |
| Age                | 0.73                | 0.25 to 1.2    | 0.003    |
| Study design       | -0.45               | -1.2 to 0.30   | 0.23     |

Sub-group analysis based on geographical region and age of children

Subgroup analysis showed that the prevalence of STHs was 44% (95% CI: 31–58%) in SNNPR, 34% (95% CI: 28–41%) in Amhara region, 31% (95% CI: 19–43%) in Oromia region and 10% (95% CI: 7–12%) in Tigray region as shown in Fig. 6. The age-related prevalence was 51% (95% CI: 45–56%) in school-age children and 32% (95% CI: 20–44%) in preschool-age children ($p = 0.003$) as shown in Fig. 7. Subgroup analysis by publication year showed that the pooled prevalence of STHs between 1995–2012 years was 44% (95% CI: 30–57%) while, it was 30% (95% CI: 25–34%) for studies conducted between 2013–2020 years (Fig. 8). In summary, STHs were more common in SNNPR among school-age children in studies published between 1990–2012 as shown in Table 3.
performed subgroup analysis based on study design and the result showed that the prevalence of STHs was 34% (95% CI: 29–39%) for cross sectional study, 25% (95% CI: 23–28%), 4% (95% CI: 3–5%) for prospective study and 20% (95% CI: 15–26%) for case-control study (not shown). This indicates that the overall prevalence is almost the same as the prevalence of studies with cross sectional study design and was not affected by other study designs.

| Variables                           | No. of studies | Sample cases | Prevalence (95% CI) | Heterogeneity | P-value |
|-------------------------------------|----------------|--------------|---------------------|---------------|---------|
| **Region**                          |                |              |                     |               |         |
| Addis Ababa city                    | 1              | 296          | 10                  | 3(2–6%)       | -       |
| Amhara region                       | 36             | 36809        | 12374               | 34(28–41%)    | 8325.55 | 99.58  | P < 0.001 |
| Benishangul-Gumuz region            | 1              | 422          | 35                  | 8(6–11%)      | -       |
| Oromia region                       | 20             | 9119         | 2780                | 31(19–43%)    | 9070.41 | 99.79  | P < 0.001 |
| South Region                        | 22             | 9379         | 3869                | 44(31–58%)    | 7621.83 | 99.72  | P < 0.001 |
| Tigray region                       | 8              | 5665         | 610                 | 10(7–12%)     | 66.61   | 89.49  | P < 0.001 |
| **Age**                             |                |              |                     |               |         |
| School                              | 73             | 55731        | 18225               | 36(31–42%)    | 27820.22 | 99.74  | P < 0.001 |
| Preschool                           | 13             | 5577         | 1408                | 20(11–29%)    | 1764.59 | 99.32  | P < 0.001 |
| Both                                | 2              | 382          | 45                  | 6(4–9%)       | -       |
| **Year of publication**             |                |              |                     |               |         |
| 1997–2012                           | 22             | 12831        | 4607                | 44(30–57%)    | 14221.00 | 99.85  | P < 0.001 |
| 2013–2020                           | 66             | 48859        | 15071               | 30(25–34%)    | 15324.02 | 99.58  | P < 0.001 |
| **Overall**                         | 88             | 61690        | 19678               | 33(28–38%)    | 30360.02 | 99.71  | P < 0.001 |

CL = confidence interval

### Table 3
Prevalence of soil-transmitted helminths (STHs) by region, age of children and year of publication among Ethiopian Children, 2020

**Prevalence Of Sths By Species**

**Ascaris lumbricoides**

Eighty five studies consisting of 58,234 children have reported that the pooled prevalence of *A. lumbricoides* was 17% (95% CI: 15 to 19%) with substantial heterogeneity ($\chi^2 = 8961.94$, P < 0.001; $I^2 = 99.06\%$). The prevalence was 27% (95% CI: 21 to 34%) in SNNPR, 14% (95% CI: 11 to 17%) in Amhara region, 15% (95% CI: 11 to 19%) in Oromia region and 6% (95% CI: 3 to 8%) in Tigray region [supplementary file 1]. The age related prevalence of *A. lumbricoides* was 18% (95% CI: 15 to 20%), in school-age children and 12% (95% CI: 8 to 17%) in preschool-age children (p = 0.06). The pooled prevalence of *A. lumbricoides* was 25% (95% CI: 19 to 31%) in studies published between 1997–2012 years and 14% (95% CI: 12 to 16%) between 2013–2020 years. A univariate meta-regression between prevalence and year of publications showed statistically significant correlation ($\beta = -0.49$ (95% CI: -1.1 to -0.07, P = 0.035, Supplementary file 2). However, regional states ($\beta$: 0.046, 95% CI: -0.12 to 0.22, p = 0.58) and age of children ($\beta$: 0.52, 95% CI: -0.02 to 1.1, p = 0.06) did not show a statistically significant relationship. Therefore, *Ascaris lumbricoides* was the most predominant species of STHs among Ethiopian children and significant decline in prevalence was observed over two decades (from late 1990s to 2020) (Table 4).
Table 4
Pooled prevalence of species specific *Ascaris lumbricoides* by region, age and year of publication among Ethiopian children, 2020

| Variables     | No. of studies | Sample cases | Prevalence (95% CI) | Heterogeneity | P-value |
|---------------|----------------|--------------|---------------------|---------------|---------|
|               |                |              |                     | Q             | I² (%)  |
| **Region**    |                |              |                     |               |         |
| Addis Ababa city | 1              | 296          | 8                   | 3(1–5%)       | -       | -       |
| Amhara region  | 35             | 34419        | 5311               | 14(11–17%)    | 3356.20 | 98.99   | P < 0.001 |
| Oromia region  | 19             | 8475         | 1271               | 15(11–19%)    | 934.49  | 98.07   | P < 0.001 |
| South Region   | 22             | 9379         | 2374               | 27(21–34%)    | 4265.90 | 99.51   | P < 0.001 |
| Tigray region  | 8              | 5665         | 375                | 6(3–8%)       | 148.81  | 95.30   | P < 0.001 |
| **Age**       |                |              |                     |               |         |
| School        | 70             | 52275        | 8509               | 18(15–20%)    | 7820.37 | 99.12   | P < 0.001 |
| Preschool     | 13             | 5577         | 822                | 12(8–17%)     | 892.82  | 98.66   | P < 0.001 |
| Both          | 2              | 382          | 8                  | 2(1–4%)       | -       | -       |         |
| **Year of publication** | | | | | | |
| 1990–2012     | 22             | 12831        | 2841               | 25(19–31%)    | 4111.93 | 99.49   | P < 0.001 |
| 2013–2020     | 63             | 45403        | 6498               | 14(12–16%)    | 4838.10 | 98.72   | P < 0.001 |
| Overall       | 85             | 58234        | 9339               | 17(15–19%)    | 8961.94 | 99.06   | P < 0.001 |

CL = confidence interval
### Trichuris trichiura

Seventy six studies included of 54,854 children have reported that the pooled prevalence of *Trichuris trichiura* was 6% (95% CI: 6 to 7%) with considerable heterogeneity ($\chi^2 = 3766.86, P < 0.001; I^2 = 98.01\%$). The pooled prevalence was 11% (95%CI: 11–13%) in SNNPR, 10% (95%CI: 8–13%) in Oromia region, 4% (95%CI: 3–4%) in Amhara region and 1% (95%CI: 0–2%) in Tigray region and 1 [supplementary file 3]. The age related prevalence was also 7% (95%CI: 6% to 8%) among school-age children and 4% (95%CI: 2–6%) among preschool-age children ($p = 0.24$). The pooled prevalence of *T. trichura* was 14% (95% CI: 12–17%) in studies conducted between 1997–2013 years and 4% (95% CI: 4–24%) between 2013–2020 years. A univariate meta-regression between prevalence and year of publications showed statistically significant correlation ($B = -0.78, 95\% CI: -1.5 to -0.069, p = 0.03,$ Supplementary file 4). However, regional states ($B: 0.003, 95\% CI: -0.22 to 0. 0.23, p = 0.97$) and age of children ($B: 0.46, 95\% CI: -0.29 to 1.2, p = 0.23$) did not show a statistically significant relationship. The bottom line is that the rate of infection of *Trichuris trichiura* among Ethiopian children decreased significantly after starting of MDA as detailed in Fig. 5.

### Hookworms

Seventy six studies consisting of 54,854 children have also reported the pooled prevalence of Hookworms. Hence, the pooled prevalence on analysis was 12% (95% CI: 10 to 13%) with substantial heterogeneity ($\chi^2 = 7920.16, P < 0.001; I^2 = 99.05\%$). The pooled prevalence of hookworms was 12% (95%CI: 9–15%) in SNNPR, 16% (95%CI: 13–19%) in Amhara region, 6% (95%CI: 5–8%) in Oromia region, and 3% (95%CI: 2–4%) in Tigray region as shown in supplementary file 5. The age related prevalence of hookworms was 13% (95%CI: 11% to 15%) among school-age children and 2% (95%CI: 1–3%) among preschool-age children ($p = 0.01$). The pooled prevalence of hookworms was 13% (95% CI: 9–15%) in studies conducted between 1997–2012 years and 11% (95% CI: 9–13%) in studies between 2013–2020 years.

A univariate meta-regression between prevalence and age of children showed statistically significant correlation ($B = 1.03, 95\% CI: 0.27 to 1.8, p = 0.01,$ supplementary file 6A). In Addition, meta-regression of the prevalence and regional states ($B: -0.20, 95\% CI: -0.40 to 0.00$) showed no significant relationship.

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### Table 5

Pooled prevalence of species specific *Trichuris trichiura* by region, age and year of publication among Ethiopian children, 2020

| Variables               | No. of studies | Sample cases | Prevalence (95% CI) | Heterogeneity | P-value |
|-------------------------|----------------|--------------|---------------------|---------------|---------|
|                         |                |              |                     | Q             | I² (%)  |
| Region                  |                |              |                     |               |         |
| Addis Ababa city        | 1              | 296          | 2                   | 1(0–2%)       | -       | -       |
| Amhara region           | 28             | 31555        | 1186                | 4(3–4%)       | 528.28  | 94.89   | P < 0.001 |
| Oromia region           | 19             | 8738         | 1089                | 10(8–13%)     | 1282.36 | 98.60   | P < 0.001 |
| South Region            | 22             | 9379         | 949                 | 11(9–13%)     | 1728.08 | 98.78   | P < 0.001 |
| Tigray region           | 6              | 4886         | 86                  | 1(0–2%)       | 61.86   | 91.92   | P < 0.001 |
| Age                     |                |              |                     |               |         |
| School                  | 63             | 49327        | 3093                | 7(6–8%)       | 3318.18 | 98.13   | P < 0.001 |
| Preschool               | 12             | 5267         | 211                 | 4(2–6%)       | 443.50  | 97.52   | P < 0.001 |
| Both                    | 1              | 260          | 8                   | 3(2–6%)       | -       | -       |         |
| Year of publication     |                |              |                     |               |         |
| 1990–2012               | 20             | 11786        | 1374                | 14(12–17%)    | 2176.26 | 99.13   | P < 0.001 |
| 2013–2020               | 56             | 43068        | 1938                | 4(4–5%)       | 1569.21 | 96.50   | P < 0.001 |
| Overall                 | 76             | 58234        | 9339                | 6(6–7%)       | 3766.86 | 98.01   | P < 0.001 |

CL = confidence interval
to -0.005, p = 0.045, supplementary file 6B) revealed a significant correlation. However, year of publication (β: -0.09, 95% CI: -0.79 to 0.61, p = 0.81) did not show a statistically significant relationship. In summary, Hookworms were more prevalent among children in Amhara region compared to other regions and among school-age children compared to preschool-age children (Table 6).

| Variables          | No. of studies | Sample cases | Prevalence (95% CI) | Heterogeneity | P-value |
|--------------------|----------------|--------------|---------------------|---------------|---------|
| Region             |                |              |                     |               |         |
| Benishangul-Gumuz  | 1              | 422          | 35                  | 8(6–11%)      | -       |
| Amhara region      | 32             | 35678        | 6171                | 16(13–19%)    | 5256.02 | 99.41   | P < 0.001 |
| Oromia region      | 15             | 6763         | 434                 | 6(5–8%)       | 392.85  | 96.44   | P < 0.001 |
| South Region       | 20             | 8761         | 950                 | 12(9–15%)     | 793.61  | 97.61   | P < 0.001 |
| Tigray region      | 8              | 5665         | 144                 | 3(2–4%)       | 96.14   | 92.72   | P < 0.001 |
| Age                |                |              |                     |               |         |
| School             | 67             | 53289        | 7648                | 13(11–15%)    | 7814.96 | 99.16   | P < 0.001 |
| Preschool          | 8              | 3740         | 102                 | 2(1–3%)       | 33.50   | 79.10   | P < 0.001 |
| Both               | 1              | 260          | 4                   | 2(1–4%)       | -       | -       |
| Year of publication|                |              |                     |               |         |
| 1990–2012          | 19             | 11253        | 1534                | 13(9–15%)     | 1346.55 | 98.66   | P < 0.001 |
| 2013–2020          | 57             | 46036        | 6220                | 11(9–13%)     | 6088.71 | 99.08   | P < 0.001 |
| Overall            | 76             | 57289        | 7754                | 12(10–13%)    | 7920.16 | 99.05   | P < 0.001 |

CL = confidence interval

**Strongyloides stercoralis**

Twenty six studies consisting of 11,748 children have reported that the pooled prevalence of *Strongyloides stercoralis* was 1% (95% CI: 1 to 2%). The pooled prevalence of *Strongyloides stercoralis* was 3% (95%CI: 1–4%) in Amhara region, 1% (95% CI: 1–2%) in SNNPR, 1% (95% CI: 0–1%) in Oromia region and 0% (95% CI: 0–1%) in Tigray region as shown in supplementary file 7. The prevalence was 1% (95% CI: 1% to 2%) in school-age children. The pooled prevalence of *Strongyloides stercoralis* was 1% (95% CI: 1–2%) in studies done between 1997–2012 years and 2% (95% CI: 1–2%) between 2013–2020.

A univariate meta-regression between prevalence and regional states showed statistically significant correlation (B= -0.30, 95% CI: -0.56 to -0.03, p = 0.03, supplementary file 8). However, year of publication (β: -0.17, 95% CI: -0.70 to 1.0, p = 0.70) and age of children (β: -0.02, 95% CI: -0.96 to 0.92, p = 0.97) did not show a statistically significant relationship. Therefore, *Strongyloides stercoralis* is more common among children in Amhara region compared to other regions (Table 7). For further details, the summary of species specific STHs presented on Table 8.
### Table 7

**Pooled prevalence of species specific Strongyloides stercoralis by region, age and year of publication among Ethiopian children, 2020**

| Variables          | No. of studies | Sample cases | Prevalence (95% CI) | Heterogeneity | P-value |
|--------------------|----------------|--------------|---------------------|---------------|---------|
| **Region**         |                |              |                     |               |         |
| Amhara region      | 11             | 5131         | 163                 | 3(1–4%)       | 116.39  |
|                    |                |              |                     |               | 91.41   |
|                    |                |              |                     |               | P < 0.001 |
| Oromia region      | 5              | 1566         | 10                  | 1(0–1%)       | 2.13    |
|                    |                |              |                     |               | 0.00    |
|                    |                |              |                     |               | P = 0.71 |
| South Region       | 7              | 3149         | 54                  | 1(1–2%)       | 35.77   |
|                    |                |              |                     |               | 83.23   |
|                    |                |              |                     |               | P < 0.001 |
| Tigray region      | 3              | 1902         | 9                   | 0(0–1%)       | -       |
|                    |                |              |                     |               | -       |
|                    |                |              |                     |               | -       |
| **Age**            |                |              |                     |               |         |
| School             | 23             | 10134        | 204                 | 1(1–2%)       | 150.65  |
|                    |                |              |                     |               | 85.40   |
|                    |                |              |                     |               | P < 0.001 |
| Preschool          | 2              | 1492         | 30                  | 0(0–1%)       | -       |
|                    |                |              |                     |               | -       |
|                    |                |              |                     |               | -       |
| Both               | 1              | 122          | 2                   | 2(0–6%)       | -       |
|                    |                |              |                     |               | -       |
|                    |                |              |                     |               | -       |
| **Year of publication** |        |              |                     |               |         |
| 1990–2012          | 11             | 5653         | 79                  | 1(1–2%)       | 141.55  |
|                    |                |              |                     |               | 90.11   |
|                    |                |              |                     |               | P < 0.001 |
| 2013–2020          | 15             | 6095         | 157                 | 2(1–2%)       | 6088.71 |
|                    |                |              |                     |               | 72.96   |
|                    |                |              |                     |               | P < 0.001 |
| **Overall**        | 26             | 11748        | 236                 | 1(1–2%)       | 179.49  |
|                    |                |              |                     |               | 86.07   |
|                    |                |              |                     |               | P < 0.001 |
| **CL = confidence interval** |        |              |                     |               |         |

### Table 8

**Summary of species-specific pooled prevalence estimates of STHs among Ethiopian children, 2020**

| Parasites                         | Number of studies | Sample size | positives | Prevalence (%) | 95% CI | Heterogeneity | P-value |
|-----------------------------------|-------------------|-------------|------------|----------------|--------|---------------|---------|
| *Ascaris lumbricoides*            | 85                | 58234       | 9339       | 17             | 15–19%| 8961.94       | 99.06   |
| *Trichuris trichiura*             | 76                | 54854       | 3312       | 6              | 6–7%  | 3766.86       | 98.01   |
| **Hookworms**                     | 76                | 57289       | 7754       | 12             | 10–13%| 7920.16       | 99.05   |
| *Strongyloides stercoralis*       | 26                | 11748       | 236        | 1              | 1–2%  | 179.49        | 86.07   |

**CL = confidence interval**

**Intesnity Of Sths Infection**

Only 13 out of 88 studies included 5,676 children reported about intensity of infection of STHs. Low intensity of infection of *A. lumbricoides* was observed in 16% (95% CI: 10 to 21%, supplementary file 9) children. Moderate and high intensity of infections of *A. lumbricoides* were observed in 13% (95% CI: 7 to 19%, supplementary file 10) and 6% (95% CI: 2 to 11%, supplementary file 11) of children, respectively. Low, moderate and high intensity of infections of *T. trichiura* were observed in 16% (95% CI: 12 to 20%, supplementary 12), 3% (95% CI: 2 to 4%, supplementary file 13), 1% (95% CI: 1 to 2%, supplementary file 14) children, respectively. This review also showed that low, moderate and high intensity of infections of Hookworms were recorded in 20% (95% CI: 10 to 29%, supplementary file 15), 4% (95% CI: 2 to 6%, supplementary file 16) and 5% (95% CI: 0 to 11%, supplementary file 17) children, respectively.
Regional distribution of eligible studies and risk zones (RZs) for STHs infections

The highest numbers of studies were reported from Amhara 36 (40.90%) and SNNPR 22(25%). These were followed by the Oromia region 20 (22.7%), Tigray 8 (9.1%), Benishangul-Gumuz region and Addis Ababa city each with one (1.1%) study. None of the regions is classified as High Risk Zone (HRZ) according to world health organization (WHO) risk classification. SNNPR, Amhara and Oromia regions recorded STH prevalence of 44%, 34%, 31%, respectively and are classified as moderate risk zones (MRZs) while, the rest of the regions and cities recorded prevalence estimates ranging between 1–10% and are classified as Low Risk Zones (LRZs).

Discussions

The purpose of current systematic review and meta- analysis of STHs infections data analysis among Ethiopian children was to measure the impact of the ongoing control and preventive measures in the country and support the efforts undertaken to control and eliminate neglected tropical diseases (NTDs) by nurturing or supplementing useful national epidemiological data. Such studies have the potential to guide concerned bodies to focus their efforts in highly endemic areas. Although several studies have been published from different regions of Ethiopia on STHs with the earliest scientific literature dating back 1990s, the data on STHs infections remains unorganized and scattered. Therefore, organizing and locating information has the potential to inform and develop a comprehensive approach to control STH infections and target highly endemic areas with greater urgency.

The overall pooled estimate of STHs (33%) observed in the present review is in line with the study from south America 27·1% [111], but higher than study done in Iran (9.48%) [112] and Côte d'Ivoire (19.1%) [113]. The prevalence is lower than study from Nigeria (54.8%) [114] and reports from other Sub-Saharan African countries (52.4–65.8%). The variation between the findings might be attributed to differences in sensitivity and specificity of diagnostic methodology, environmental factors such as soil moisture, humidity, temperature and level of participants’ hygiene and sanitation. In addition, our review included more recent surveys that the ongoing MDA and Sustainable water, sanitation, and hygiene (WASH) programs decreased the prevalence of STHs in Ethiopian children unlike the systematic review from Nigeria which included old studies from the year 1985 [114].

Subgroup analysis of the current review also showed that STHs are more common in SNNPR, Amhara and Oromia regions, although variation among the regional states was not statistically significant (p = 0.70). The majority of these infections are related to low standard of living, poor socioeconomic status, poor personal hygiene, and poor environmental sanitation. The higher prevalence of STHs infection among children in SNNPR, Amhara and Oromia regions might be also related to the high rainfall, forest and low temperature which favors the survival and transmission of the helminths in these regions. The lowest prevalence in Addis Ababa, capital city of Ethiopia, might be due to advanced life style, good personal hygiene and good quality of life.

Our review suggests that the risk of STH infections has decreased from 44–30% in studies conducted between 1997–2012 and 2013–2020 respectively, although the decline is not statistically significant (p = 0.45). On one hand, prevalence might have declined in some parts due to improvement in living conditions globally, Ethiopia is not an exceptional and expansion of major deworming efforts. On the other hand, the increase in population growth in Ethiopia is tremendous and therefore, might have increased the numbers infected and resulted in slight decline in rate. It is also suggested that widespread of monotherapy of antiheminthics for deworming purpose might have facilitated the development of drug resistance and hence, decreased the rate of decline STHs in general and Hookworms in particular [115, 116]. If environmental and behavioral conditions are not changed at the same time that chemotherapy program is being implemented, the prevalence will tend to return to original pretreatment levels through reinfection and therefore, need holistic approach [3, 116–121]. According to WHO risk categorization, our finding (33%) indicating that MRZ of STHs requiring MDA once annually, specifically in SNNPR, Amhara and Oromia regions.

In relation to the species of STH, A. lumbricoides was the predominant species with a prevalence of 17% indicating that about one in six of Ethiopian children are living with Ascariasis. The current prevalence of the parasite is higher than the findings from other countries such as Iran (0.75%) and Sri Lanka (2.8%) which indicated that indoor and outdoor biotic contamination of the living environment arising partly from improper disposal of human waste, and partly from the integration of the lives of humans and animals of Ethiopian community might account for the still high rate of STHs infections in the country. The finding of the current review (17%) is in line with findings from South America (15.6%), studies conducted in Amhara region, Ethiopia (16.8%) and the overall burden in Sub-Saharan African countries (15%) [122]. However, it was lower than results from Nigeria (44.6%), Rwanda (38.6%), Uganda (43.5%) [123], Kenya (24.3%) [124] and previous estimate in Ethiopia (37%). The observed differences might be due variation in some factors putting population at risk of acquiring STHs such as geographical variations, life style of the community, soil
humidity and exposure to contaminated environments. In the current review, the prevalence of *A. lumbricoides* significantly decreased from 25% in 1997–2012 to 14% in 2013–2020 (*p* = 0.006). There was a 49% decline in prevalence of *A. lumbricoides* observed before the implementation of MDA program in school children compared to post MDA. This risk reduction might be related to the improved sanitation, access to better water supply, improved personnel hygiene or the higher efficacy of the available treatments against *A. lumbricoides* [115]. In support of this, a local study conducted on the efficacy of albendazole and mebendazole indicated that the drugs have 95% efficacy in decreasing the burden of the parasite in Ethiopia [125].

The pooled prevalence of 6% observed for *T. trichiura* was higher than the 1.9% and 3.4% reported from Uganda [112] and Rwanda [114], respectively. The present finding is however, lower than the reports of the disease burden of Sub-saharan Africa (13%) [106], Nigeria (18.2%) [110] and Cameroon (15.6%) [111]. The variations might be due to geographical variations, life style of the community, soil humidity and exposure to contaminated environments. Meta-regression analysis by year of publication revealed that the prevalence of *T. trichiura* decreased from 14% in 1997–2012 to 4% in 2013–2020 (*p* = 0.03). The reason behind the substantial decrease in prevalence of *T. trichiura* in the country during the study period might be due to the synergistic effect of overall improvements in sanitation, personnel hygiene and deworming programmes.

The finding of the current review showed that the prevalence of hookworms was 12% indicating that the current finding is lower than others studies conducted in Nigeria (32.7%) [114] and Uganda (18.5%) [123]. However, it was higher than studies conducted in Kenya (0.4%) [124], Rawanda (1.8%) [126] and Cameroon (3.9%) [127]. In general, increments of prevalence in our data might be attributed to the re-infection rate, low coverage or unequal distribution of MDA in all regions of the country, level of poverty (walking bare of foot) and lack of good quality of life. For instance, most Ethiopian are living in rural area and engaged in agriculture. Engagement in agricultural pursuits remains a common denominator for adult human hookworm infection, who might be serve as reservoir for reinfection of children [121]. Hookworm did not show significant trend of decrement in prevalence between 1997–2012 (13%) as compared the years between 2013–2020. This is in contrast to study conducted in Nepal where the revalence of Hookworms significantly decreased between 1990s to 2015 [128].

Eliminating STHs as a public health has to go beyond preventive chemotherapy for school-age children, as other group at risk also serve as reservoir of infection (preschool children and pregnant women and even adults), which might have resulted in slight decline again. It is also suggested that widespread of monotherapy of antihelminths for deworming purpose might have facilitated the development of drug resistance and hence, decreased the rate of decline STHs in general and Hookworms in particular [115, 116].

The strengths of our review include rigorous search of several databases and other sources to identify eligible studies on the large pediatric population infected by STHs and generate data for policymakers to strengthen or modify the already ongoing control and preventive measures on place. We also estimated the geographical distribution and identified risk areas that should be prioritized for MDA and other control interventions, which complement global efforts towards elimination of STHs and other parasitic 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 Gembela regions or scanty (Addis Ababa city and Benishangul-Gumuz region). There are a few limitations of the present meta-analysis. First, it is prudent to interpret the results of this study as 34(38.6%) of the included studies were low quality based on our quality assessment criteria. Second, in almost all of the studies included in this review, single stool sample examination were used despite multiple stool samples recommendation for standard diagnosis and therefore, there is possibility for underestimation of the prevalence. Almost all studies included the current analyses examined the stool specimens for many parasites at a time and the diagnostic performance of such an approach is not known compared to studies that examine solely for STHs, such diagnostic approach might affect the detection rate and prevalence estimates of STHs infections. Third WHO has recommended Kato-Katz method as the best and most reliable diagnostic tool with better efficacy, accuracy and predictive value than other techniques in resource poor settings [129]. However, only 39.8% of the studies reported the use of Kato-Katz method or in combination with other methods. Morbidity due to STH infections is a result of worm burden (number of eggs per gram of feces), otherwise called infection intesity. The disease prevalence is commonly combined with the intensity of infection to assess the epidemiological situation for STH infections and to classify communities into transmission categories, which enables the determination of the appropriate strategies for treatment and control [130]. However, only few studies (13 out of 88) reported the intensity of infection of species-specific STHs and thus, difficult to reach on definitive conclusion about intensity of infection of STH in Ethiopia children. Therefore, there is urgent need of large-scale study to assess the intensity of infection of STH in children using sensitive diagnostic tool on repeated stool sample. Finally, the review protocol was not registered a head of actual meta-analysis, which could be source of bias.
Conclusions

Despite efforts made to reduce, STHs infection is still highly prevalent across Ethiopian region with some degree of variation. Southern, Amhara and Oromia regional states carry the highest burden. We observed a decreased prevalence of STHs among Ethiopian children post MDA compared to preMDA, but the decrease is not statistically significant. *A. lumbricoides* had the highest prevalence among STHs. *A. lumbricoides* and *T. trichiura* were the most prevalent species in the Southern region while, hookworms recorded the highest prevalence in Amhara region. With effort made by the country in eradicating STHs infections, none of the regions in the country is classified as HRZ according to WHO risk classification. Southern, Amhara and Oromia regions carried moderate burden and are classified as MRZs and therefore annual MDA is recommended while, the rest of the regions and city are classified as low risk zones LRZs. We hope that the findings of the current study provide valuable information to the policymakers, National Health Bureau and other concerned bodies, specifically on endemicity of STHs, national and regional distribution and their prevalence and species distribution in Ethiopia.

Lists Of Abbreviations

STH, soil transmitted helminth; MRZ, moderate risk zone; HRZ, high risk zone; LRZ, low risk zone; MDA, mass drug administration; GRADE, Grading of Recommendations Assessment, Development and Evaluation; CI, confidence interval; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; WHO, world health organization; NTDs, Neglected tropical diseases.

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 are available from the corresponding author on reasonable request.

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

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