Review Article

Strongyloidiasis in Africa: Systematic Review and Meta-Analysis on Prevalence, Diagnostic Methods, and Study Settings

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Background. Strongyloidiasis is an intestinal parasitic infection mainly caused by Strongyloides stercoralis. Although it is a predominant parasite in tropics and subtropics where sanitation and hygiene are poorly practiced, the true prevalence of strongyloidiasis is not known due to low-sensitivity diagnostic methods. Objective. This systematic review and meta-analysis is aimed at determining the pooled prevalence of strongyloidiasis in African countries, stratified by diagnostic methods, study settings, and patients. Methods. Cross-sectional studies on strongyloidiasis published in African countries from the year 2008 up to 2018 in PubMed and Google Scholar databases and which reported at least one Strongyloides spp. infection were included. Identification and screening of eligible articles were also done. Articles whose focus was on strongyloidiasis in animals, soil, and foreigners infected by Strongyloides spp. in Africa were excluded. The random effects model was used to calculate the pooled prevalence of strongyloidiasis across African countries as well as by diagnostic methods and study settings. The heterogeneity between studies was also computed. Result. A total of 82 studies were included. The overall pooled prevalence of strongyloidiasis was 2.7%. By individual techniques, the pooled prevalence of strongyloidiasis was 0.4%, 1.0%, 3.4%, 9.3%, 9.6%, and 19.4% by the respective direct saline microscopy, Kato-Katz, formol ether concentration, polymerase chain reaction, Baermann concentration, and culture diagnostic techniques. The prevalence rates of strongyloidiasis among rural community, school, and health institution studies were 6.8%, 6.4%, and 0.9%, respectively. The variation on the effect size comparing African countries, diagnostic methods, study settings, and patients was significant (P ≤ 0.001). Conclusions. This review shows that strongyloidiasis is overlooked and its prevalence is estimated to be low in Africa due to the use of diagnostic methods with low sensitivity. Therefore, there is a need for using a combination of appropriate diagnostic methods to approach the actual strongyloidiasis rates in Africa.

1. Introduction

Strongyloides stercoralis is one of the soil-transmitted helminths (STHs) that cause strongyloidiasis. There are more than 60 species in the genus which parasitize the duodenum of the small intestine of humans and domestic mammals [1]. Only two species S. stercoralis and S. fuelleborni are known to infect human beings. Strongyloides stercoralis is distributed in tropical and subtropical areas whereas S. fuelleborni infection is found in Papua New Guinea and sporadically in Africa [2]. The true prevalence of strongyloidiasis is underestimated and underreported due to the use of diagnostic methods with poor sensitivity [3]. An estimated 370 million strongyloidiasis occur globally [4], being 90% of them in sub-Saharan Africa, Southeast Asia, Latin America, Oceanian countries, and the Caribbean islands and is related to poor sanitation and hygiene practices [5]. Studies showed that high numbers of strongyloidiasis occur among children [6] and immunocompromised individuals [7]. Several factors including malnutrition, autoimmune diseases, and taking corticosteroid drugs that impaired the immune system may contribute for the high prevalence of strongyloidiasis [8].

In developing countries, the risk of acquiring strongyloidiasis is higher in rural dwellers, having low socioeconomic
status [9] and poor sanitation infrastructures [10]. Infection ranges from asymptomatic to life-threatening clinical manifestations depending on the level of immunity [11]. The infection appears when the filariform larva enters the human body through skin penetration and crosses the lung during larva migration, and the adult reaches the small intestine. The larvae may cause skin rashes, dry cough, and recurrent sore throat whereas the adult stage of the parasite may also cause abdominal pain, loss of appetite, diarrhea, blood in stool, epigastric pain, and bloating, but most frequently, the infection is asymptomatic [12].

Strongyloidiasis is detected by microscopic-based diagnostic methods like direct saline microscopy (DSM) [3], formal ether concentration technique (FECT) [13], Baermann concentration technique (BCT) [14], agar plate technique (APT) [15], and immunological [16] and molecular-based techniques [17].

The Baermann concentration technique may increase the detection rate of strongyloidiasis by 3.6–4 times compared to the FECT or DSM technique [18]. In the same way, serological assays [16] and real-time polymerase chain reaction (RT-PCR) techniques have shown to be more sensitive diagnostic tools for S. stercoralis detection [17].

The sensitivity of BCT, APT, RT-PCR, and ELISA is good, but not enough. Moreover, they have limitations for application in countries of poor resource in Africa. Because of that, a combination of techniques is the recommended approach for diagnosing the infection. Therefore, this systematic review and meta-analysis is aimed at providing an overview of the prevalence of strongyloidiasis across African countries, stratified by diagnostic methods, study settings, and patients.

2. Materials and Methods

A search on the databases PubMed and Google Scholar was done for studies written in English from the year 2008 up to 2018. Keywords used in the search were “Strongyloidiasis,” “Strongyloides,” “Strongyloides stercoralis,” and “Soil-transmitted helminths” in each African country. The search for electronic data of studies was conducted between July 2019 and August 2019. Identification, screening, and checking the eligibility and the inclusion of the relevant studies were done following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) (Figure 1). The articles extracted from the two databases were first screened to remove duplication. Furthermore, the articles were screened by reading their abstracts and the full articles and then the articles which did not investigate the prevalence of strongyloidiasis.

2.1. Inclusion Criteria. All cross-sectional studies from 2008 to 2018 conducted in African countries among patients or any participants in Africa and diagnosed by DSM, KK, FECT, BCT, culture, PCR, or a combination of these diagnostic techniques and obtained at least one positive for Strongyloides spp. were included. Including only PubMed and Google Scholar databases was the limitation.

2.2. Exclusion Criteria. All studies on strongyloidiasis in animals, soil, foreigners in African countries or imported cases, nondefined study population, sample sources other than stool, analysis of S. stercoralis-positive cases only, method comparisons, case studies, cohort studies, duplications, articles conducted before the year 2008, and review articles done in African countries were excluded. The suitability of all studies according to the defined criteria was judged independently by two different authors. Any differences in judgment were resolved by discussion among the authors.

For each selected paper, the following information was recorded: number of infected individuals, number of examined individuals, country name, types of diagnostic method used, study setting where date were collected, and types of disease recorded in health institution. The pooled prevalence of strongyloidiasis in African countries as well as by each diagnostic method, study settings, and among patients was computed using a random effects model.

The meta-analysis was performed using comprehensive meta-analysis 2.2 software (Biotstat Inc., Englewood, NJ, USA). The pooled overall prevalence of strongyloidiasis at 95% confidence interval (CI) in African countries was calculated using a random effects model. The pooled prevalence of strongyloidiasis by diagnostic methods, study settings, and patients was calculated in the subgroup analysis. The forest plot was reported, and separate meta-analyses were performed to evaluate the effect of diagnostic methods, study settings, and patients in health institutions with strongyloidiasis. Heterogeneity (the difference between studies) by country, diagnostic methods, study settings, and among patients was assessed using Cochrane (Q) value, P value, and I² and visual inspection of the forest plot. The level of significance for all tests was P ≤ 0.001. Publication bias that occurs in published studies was checked by considering effect size symmetry on funnel plot (a scatter plot of estimates). Absence of bias is presented by shape like a funnel.

3. Result

A total of 208 (90 from PubMed and 118 from Google Scholar databases) studies were identified. One hundred sixty-three studies were screened and recorded after duplications removed. One hundred twenty-one studies were found to be eligible after full-text assessment, and finally, 82 studies were included in qualitative analysis (Figure 1).

3.1. Prevalence of Strongyloidiasis. Twenty African countries having strongyloidiasis research reports and fulfilling the inclusion criteria were involved with the total participants being 96,069 (Table 1). Among the 82 studies in Africa, the prevalence of strongyloidiasis ranged from 0.1% in a study conducted in Sudan [87] to 27.1% in Côte d’Ivoire [26] (Table 1). All studies in Côte d’Ivoire used a combination of two or three diagnostic techniques including PCR, BCT, and culture techniques. One of the two studies from Mozambique also used combination of FECT, BCT, and PCR reporting a prevalence rate of 48.51% [59]. The prevalence rate 17.4% in Rwanda was reported using agar plate culture among community dwellers.
The fourth highest prevalence 10.21% (92-96%) of strongyloidiasis was from Tanzania. All the five studies conducted in Tanzania used BCT as diagnostic method, and three of which studies used PCR [90], FECT [93], or culture [94] (Table 1).

In Ethiopia, a relatively high number of participants 44,638 (45.1%) were included (Table 1) and the total pooled prevalence of strongyloidiasis was 1.1% (1.0-1.2) (Figure 2). Most of the studies (13/18; 72.2%) used FECT, whereas four studies (22.2%) used DSM as a means of diagnosis. The majority of the studies (12/18: 66.7%) were conducted among patients visiting the health institutions for different ailments (Table 1).

In Nigeria, a total of 14,294 (14.8%) study participants were involved in 23 (27.7%) studies (Table 1). The pooled prevalence of strongyloidiasis in Nigeria was 4.9% (4.5-5.2%) (Figure 2). Nineteen (82.6%) and three (13.0%) of the studies used FECT and DSM diagnosis in Nigeria, respectively. Only one study used culture diagnostic method. In addition, 15 (65.2%) and eight (34.8%) studies were conducted among school-age children and patients, respectively (Table 1).

Low pooled prevalence of strongyloidiasis was reported from studies conducted in Sudan (0.14%) [87], Zambia (0.5%) [97], and Burkina Faso (0.5%) [22]. Among studies conducted in Sudan, one study conducted using DSM [88] and the other by FECT [87] had low sensitivity to strongyloidiasis detection. The studies conducted in Burkina Faso and Zambia used DSM as a diagnostic method (Table 1).

The forest plots (Figure 2) indicated the pooled prevalence of strongyloidiasis among 82 studies in Africa which was 3.4% (95% CI: 2.0-5.5%) using random effects model. The highest pooled prevalence 22.6% of strongyloidiasis was recorded in Côte d’Ivoire followed by Mozambique 22.6% (19.6-25.9%), Rwanda 17.4% (14.5-20.9%), and Egypt 15.7% (10.1-23.4%) (Figure 2). The heterogeneity of studies across African countries was high ($Q = 2782.625, I^2 = 99.317\%, P \leq 0.001$) (Figure 2).

3.2 Diagnostic Methods of Strongyloidiasis. Regarding the diagnostic methods of S. stercoralis, most studies (69, 84.15%) used DM, KK, or FECT. Most of the studies (43, 52.4%) used FECT for diagnosing the infection in Africa (Figure 3). Among studies using single diagnostic methods, high pooled prevalence of strongyloidiasis was recorded 19.4% in stool culture followed by 9.6% in PCR and 9.3% in BCT detection methods (Figure 3). The highest pooled prevalence rate 32.8% of strongyloidiasis was obtained by using a combination of BCT, FECT, and PCR diagnostic methods (Figure 3). The low prevalence rates of strongyloidiasis 3.4%, 0.4%, and 1.0% were also obtained using FECT, KK, and DSM diagnostic methods, respectively (Figure 3).

Forest plot (Figure 3) indicated that the pooled prevalence of strongyloidiasis in Africa across different diagnostic
| Authors’ information and reference | Diagnostic methods | Study settings | $S. \text{ stercoralis}$ Pos (n, %) | Sample size |
|-----------------------------------|--------------------|----------------|----------------------------------|------------|
| Dacal et al., 2018, Angola [19]   | PCR                | School         | 75 (21.4)                        | 351        |
| Bocanegra et al., 2015, Angola [20]| FECT               | School         | 1 (0.07)                         | 1425       |
| de Alegria et al., 2017, Angola [21]| BCT, FECT         | School         | 28 (12.2)                        | 230        |
| Karou et al., 2011, Burkina Faso [22]| DSM               | H/institution  | 6 (0.05)                         | 11,728     |
| Bopda et al., 2016, Cameroon [23] | KK                 | H/institution  | 7 (2.1)                          | 334        |
| Nsagha et al., 2016, Cameroon [11]| FECT               | H/institution  | 2 (0.7)                          | 300        |
| Kuete et al., 2015, Cameroon [24]| FECT               | H/institution  | 4 (0.9)                          | 428        |
| Becker et al., 2015, Côte d’Ivoire [25]| BCT, culture, PCR | Community      | 56 (21.9)                        | 256        |
| Glinz et al., 2010, Côte d’Ivoire [26]| BCT, culture     | School         | 68 (27.1)                        | 251        |
| Rayan et al., 2011, Egypt [27]    | BCT, FECT, culture, PCR | H/institution  | 18 (15.7)                        | 115        |
| Roka et al., 2013, Equatorial Guinea [28]| FECT            | H/institution  | 28 (10.3)                        | 273        |
| Roka et al., 2012, Equatorial Guinea [29]| FECT            | H/institution  | 23 (8.8)                         | 260        |
| Amor et al., 2016, Ethiopia [6]   | BCT, FECT, PCR    | School         | 82 (20.7)                        | 396        |
| Abdia et al., 2017, Ethiopia [30]| FECT               | School         | 3 (0.7)                          | 408        |
| Ramos et al., 2014, Ethiopia [31] | DSM                | H/institution  | 92 (0.3)                         | 32191      |
| Zeynudin et al., 2013, Ethiopia [32]| FECT              | H/institution  | 6 (6.6)                          | 91         |
| Assefa et al., 2009, Ethiopia [33]| FECT               | H/institution  | 28 (7.4)                         | 378        |
| Wegayehu et al., 2013, Ethiopia [34]| FECT             | Community      | 51 (5.9)                         | 858        |
| Huruy et al., 2011, Ethiopia [35]| DSM                | H/institution  | 12 (3.1)                         | 384        |
| Gedle et al., 2015, Ethiopia [36] | FECT               | H/institution  | 5 (1.6)                          | 305        |
| Adera et al., 2013, Ethiopia [37]| FECT               | School         | 27 (3.4)                         | 788        |
| Derso et al., 2016, Ethiopia [38] | DSM                | H/institution  | 6 (1.6)                          | 384        |
| Fekadu et al., 2013, Ethiopia [39]| FECT               | H/institution  | 36 (10.5)                        | 343        |
| Abate et al., 2013, Ethiopia [40]| FECT               | H/institution  | 8 (2.0)                          | 410        |
| Alemu et al., 2017, Ethiopia [41]| FECT               | H/institution  | 4 (1.8)                          | 220        |
| Teklemariam et al., 2013, Ethiopia [42]| FECT            | H/institution  | 15 (4.0)                         | 371        |
| Legesse et al., 2010, Ethiopia [43]| FECT               | School         | 1 (0.3)                          | 381        |
| Hailu et al., 2015, Ethiopia [44]| FECT               | H/institution  | 5 (0.05)                         | 100        |
| Nyantekyi et al., 2010, Ethiopia [45]| FECT             | Community      | 38 (13.2)                        | 288        |
| Chala, 2013, Ethiopia [46]        | DSM                | H/institution  | 73 (1.2)                         | 6342       |
| M’bondoukwé et al., 2018, Gabon [47]| DSM               | Community      | 10 (3.7)                         | 270        |
| Janssen et al., 2015, Gabon [48]  | Culture            | H/institution  | 10 (4.0)                         | 252        |
| M’bondoukwé et al., 2016, Gabon [49]| DSM              | H/institution  | 1 (1.0)                          | 101        |
| Adu-Gyasi et al., 2018, Ghana [50]| FECT               | Community      | 14 (0.9)                         | 1569       |
| Nkrumah et al., 2011, Ghana [51]  | DSM                | Hospital       | 6 (0.6)                          | 1080       |
| Forson et al., 2017, Ghana [52]   | FECT               | School         | 1 (0.3)                          | 300        |
| Yatich et al., 2009, Ghana [53]   | BCT                | H/institution  | 29 (3.9)                         | 746        |
| Sam et al., 2018, Ghana [54]      | FECT               | School         | 20 (5.1)                         | 394        |
| Cunningham et al., 2018, Ghana [55]| PCR               | Community      | 5 (1.1)                          | 448        |
| Kagira et al., 2011, Kenya [56]   | DSM                | H/institution  | 3 (9.7)                          | 31         |
| Walson et al., 2010, Kenya [57]   | FECT               | Community      | 20 (1.3)                         | 1541       |
| Arndt et al., 2013, Kenya [58]    | FECT               | Community      | 5 (3.3)                          | 153        |
| Meurs et al., 2017, Mozambique [59]| FECT, BCT, PCR    | Community      | 147 (48.5)                       | 303        |
| Cerveja et al., 2017, Mozambique [60]| DSM              | H/institution  | 5 (1.3)                          | 371        |
| Chukwuma et al., 2009, Nigeria [61]| FECT               | School         | 13 (5.9)                         | 220        |
| Uhuo et al., 2011, Nigeria [62]   | FECT               | School         | 4 (0.5)                          | 800        |
| Wosu and Onyeabor, 2014, Nigeria [63]| FECT            | School         | 11 (3.6)                         | 304        |
| Simon-oke et al., 2014, Nigeria [64]| DSM              | School         | 23 (12.8)                        | 180        |
methods was 8.0% (95% CI: 3.9–15.9%) using random effects model. Heterogeneity of studies through different diagnostic approaches was high \((Q = 3497.655, I^2 = 99.696\%, P \leq 0.001)\) (Figure 3).

### 3.3. Strongyloidiasis by Study Settings.
Among the total studies, 35 (42.68%) studies were conducted in health institutions followed by 27 (32.93%) in schools and 18 (21.95%) in rural communities (Figure 4).

The forest plot (Figure 4) shows the pooled prevalence of strongyloidiasis across different study settings in Africa using random effects model which was 1.4% (95% CI: 0.5–3.9%). Heterogeneity of studies among the study sites in the African countries was high \((Q = 1856.455, I^2 = 9.785\%, P \leq 0.001)\) (Figure 4).

#### 3.4. Strongyloidiasis In Health Institutions.
Pooled prevalence rates of 12.2%, 9.7%, and 3.6% of strongyloidiasis were obtained with the respective tuberculosis (TB), human African trypanosomiasis (HAT), and human immunodeficiency virus (HIV) cases (Figure 5).

Forest plot (Figure 5) indicates 2.3% (95% CI: 0.6–7.7%) pooled prevalence of strongyloidiasis among patients across health institutions in Africa using random effects model. Heterogeneity of studies between patients in the African

| Authors’ information and reference | Diagnostic methods | Study settings | S. stercoralis Pos (n, %) | Sample size |
|-----------------------------------|--------------------|----------------|---------------------------|-------------|
| Adekolujo et al., 2015, Nigeria [65] | FECT | H/institution | 4 (0.6) | 717 |
| Olusegun et al., 2011, Nigeria [66] | DSM | School | 2 (0.7) | 304 |
| Abaver et al., 2011, Nigeria [67] | FECT | H/institution | 3 (2.5) | 119 |
| Ivoke et al., 2017, Nigeria [68] | FECT | H/institution | 8 (1.0) | 797 |
| Ojurongbe et al., 2018, Nigeria [69] | FECT | H/institution | 2 (1.0) | 200 |
| Emeka, 2013, Nigeria [70] | FECT | School | 28 (11.0) | 255 |
| Esiet and Edet, 2017, Nigeria [71] | FECT | School | 46 (4.4) | 1055 |
| Manir et al., 2017, Nigeria [72] | FECT | School | 10 (4.0) | 252 |
| Onyido et al., 2016, Nigeria [73] | FECT | School | 1 (0.8) | 120 |
| Abah and Arene, 2015, Nigeria [74] | FECT | School | 273 (7.1) | 3826 |
| Damen et al., 2010, Nigeria [75] | FECT | School | 34 (6.8) | 500 |
| Akinbo et al., 2010, Nigeria [76] | FECT | H/institution | 23 (1.2) | 2000 |
| Ojurongbe et al., 2014, Nigeria [77] | FECT | School | 6 (3.7) | 162 |
| Amoo et al., 2018, Nigeria [78] | FECT | H/institution | 10 (4.3) | 231 |
| Ali et al., 2011, Nigeria [79] | FECT | H/institution | 4 (1.1) | 350 |
| Eke et al., 2015, Nigeria [80] | FECT | School | 63 (13.1) | 480 |
| Auta et al., 2013, Nigeria [81] | FECT | School | 12 (4.2) | 283 |
| Aniwada et al., 2016, Nigeria [82] | FECT | School | 10 (1.2) | 859 |
| Umar and Bassey et al., 2010, Nigeria [83] | Culture | School | 104 (37.1) | 280 |
| Tuyizere et al., 2018, Rwanda [84] | Culture | Community | 94 (17.4) | 539 |
| Ferreira et al., 2015, Sao Tome and Principe [85] | FECT | Community | 11 (2.5) | 444 |
| Sow et al., 2017, Senegal [86] | PCR | H/institution | 6 (6.1) | 98 |
| Babiker et al., 2009, Sudan [87] | FECT | H/institution | 2 (0.1) | 1500 |
| Mohamed et al., 2018, Sudan [88] | DSM | H/institution | 1 (0.2) | 600 |
| Knopp et al., 2014, Tanzania [89] | BCT, PCR | Community | 83 (7.4) | 1128 |
| Salim et al., 2014, Tanzania [90] | BCT | Community | 71 (6.9) | 1033 |
| Sikalengo et al., 2018, Tanzania [91] | BCT | H/institution | 89 (13.3) | 668 |
| Mhimbira et al., 2017, Tanzania [92] | BCT, FECT | Community | 161 (16.6) | 972 |
| Barda et al., 2017, Tanzania [93] | BCT, culture | School | 36 (7.1) | 509 |
| Oboth et al., 2019, Uganda [94] | KK | Refuge | 1 (0.2) | 476 |
| Stothard et al., 2008, Uganda [95] | BCT | Community | 4 (1.3) | 301 |
| Hillier et al., 2008, Uganda [96] | BCT | Community | 256 (12.4) | 2059 |
| Kelly et al., 2009, Zambia [97] | DSM | Community | 14 (0.5) | 2981 |
| Knopp et al., 2008, Zanzibar [98] | BCT, culture | Community | 7 (2.2) | 319 |
| **Total** | **2614 (2.7)** | **96,069** | | |
| Study name          | Number of articles | Event rate and 95% CI | Statistics for each study | Event rate and 95% CI |
|--------------------|--------------------|-----------------------|---------------------------|-----------------------|
| Angola             | 3                  | 0.052 0.043 0.062     | 28.860 0.000             |                       |
| Burkina Faso       | 1                  | 0.001 0.000 0.001     | -18.556 0.000            |                       |
| Cameroon           | 3                  | 0.012 0.007 0.021     | -15.733 0.000            |                       |
| Côte d'Ivoire      | 2                  | 0.245 0.209 0.284     | -10.915 0.000            |                       |
| Egypt              | 1                  | 0.157 0.101 0.235     | -6.563 0.000             |                       |
| Equatorial Guinea  | 2                  | 0.096 0.073 0.124     | -15.254 0.000            |                       |
| Ethiopia           | 18                 | 0.011 0.010 0.012     | -99.192 0.000            |                       |
| Gabon              | 3                  | 0.034 0.022 0.051     | -15.117 0.000            |                       |
| Ghana              | 6                  | 0.017 0.013 0.021     | -35.091 0.000            |                       |
| Kenya              | 3                  | 0.016 0.011 0.023     | -21.542 0.000            |                       |
| Mozambique         | 2                  | 0.226 0.196 0.259     | -13.387 0.000            |                       |
| Nigeria            | 23                 | 0.049 0.045 0.052     | -76.456 0.000            |                       |
| Rwanda             | 1                  | 0.174 0.145 0.209     | -13.697 0.000            |                       |
| Sao Tome & Princep | 1                  | 0.025 0.014 0.044     | -12.030 0.000            |                       |
| Senegal            | 1                  | 0.061 0.028 0.130     | -6.479 0.000             |                       |
| Sudan              | 2                  | 0.001 0.000 0.004     | -11.336 0.000            |                       |
| Tanzania           | 5                  | 0.102 0.093 0.111     | -43.217 0.000            |                       |
| Uganda             | 3                  | 0.092 0.082 0.103     | -35.239 0.000            |                       |
| Zambia             | 1                  | 0.005 0.003 0.008     | -19.994 0.000            |                       |
| Zanzibar           | 1                  | 0.034 0.020 0.055     | -12.573 0.000            |                       |

**Figure 2:** Forest plot of strongyloidiasis in African countries using random effects model.

| Study name               | Number of articles | Statistics for each study | Event rate and 95% CI |
|--------------------------|--------------------|---------------------------|-----------------------|
| DSM                      | 14                 | 0.004 0.004 0.005         | -85.998 0.000         |
| KK                       | 2                  | 0.010 0.005 0.020         | -12.968 0.000         |
| FECT                     | 45                 | 0.034 0.032 0.036         | -99.828 0.000         |
| BCT                      | 5                  | 0.093 0.085 0.102         | -45.854 0.000         |
| PCR                      | 3                  | 0.096 0.078 0.117         | -19.787 0.000         |
| Culture                  | 3                  | 0.194 0.172 0.219         | -18.421 0.000         |
| BCT + FECT               | 2                  | 0.157 0.138 0.179         | -21.189 0.000         |
| BCT + culture            | 3                  | 0.103 0.086 0.122         | -21.612 0.000         |
| BCT + PCR                | 1                  | 0.074 0.060 0.090         | -22.211 0.000         |
| BCT + FECT + PCR         | 2                  | 0.328 0.294 0.363         | -8.922 0.000          |
| BCT + culture + PCR      | 1                  | 0.219 0.172 0.274         | -8.420 0.000          |
| BCT + FECT + culture + PCR | 1              | 0.157 0.101 0.235         | -6.563 0.000          |

**Figure 3:** Forest plot of strongyloidiasis prevalence by diagnostic methods using random effects model.

| Study settings          | Number of articles | Statistics for each study | Event rate and 95% CI |
|-------------------------|--------------------|---------------------------|-----------------------|
| School                  | 27                 | 0.064 0.060 0.068         | -81.263 0.000         |
| Health institution      | 35                 | 0.009 0.008 0.010         | -112.389 0.000        |
| Rural community         | 18                 | 0.068 0.064 0.072         | -81.929 0.000         |
| Refugee camp            | 1                  | 0.002 0.000 0.015         | -6.157 0.000          |
| Hotel                   | 1                  | 0.001 0.000 0.005         | -9.334 0.000          |

**Figure 4:** Forest plot of strongyloidiasis prevalence by study settings using random effects model.
countries was high ($Q = 83.334, I^2 = 99.440\%$, $P \leq 0.001$) (Figure 5).

The funnel plot shows that studies were distributed symmetrically about the combined effect size that showed the absence of publication bias in this review (Figure 6).

### 4. Discussion

The prevalence of strongyloidiasis in Africa is difficult to estimate due to inadequacy of studies and absence of very high-sensitive diagnostic methods. In this review, authors clearly demonstrated that a study conducted with DSM, FECT, and KK methods provided low strongyloidiasis prevalence report in the African continent. This finding is supported by the most widely used diagnostic methods to helminthic infections including DSM, FECT, and KK which most likely fail to detect strongyloidiasis [18]. The justification for the low prevalence rates of strongyloidiasis in African in the current review might be due to the use of traditional methods (FECT, KK, and DSM), very small amount of stool sample used, and one-time stool sample collection which may give false-negative results. Moreover, single stool examination might also compromise the true prevalence of strongyloidiasis detection. For instance, single stool examination using DSM can detect the strongyloidiasis larvae in only 30% of the cases [99]. Furthermore, the intermittent excretion nature of *S. stercoralis* and chronic low-intensity infections which lead to low larval load within the stool may also affect the true prevalence [7]. Generally, most African countries use low-sensitivity diagnostic methods for strongyloidiasis detection since there is a lack of awareness and more sensitive diagnostic methods are costly and difficult to adopt in most African health institutions. As a result, they stick to using FECT and DSM with their limitations [18].

In this review, stool culture, BCT, and PCR are more sensitive methods for the diagnosis of strongyloidiasis. This finding is supported by other previous studies [15, 100]. A combination of two or three of the culture, BCT, and PCR provided better detection rate of strongyloidiasis in stool in the current review. This result agrees with a previous report [6], and better detection of strongyloidiasis was obtained using combination of BCT and other methods [101]. Nevertheless, it should be borne in mind that the sensitivity of such tests is not perfect, especially when it is performed on a single
Strongyloidiasis is distributed symmetrically using funnel standardizing diagnostic protocols of previously estimated. We encourage researchers to work on although the global burden is probably much higher than 4.1. Limitation of This Review. The use of only PubMed and Google Scholar databases as a source of articles was the limitation of this review.

5. Conclusions

This review shows that strongyloidiasis prevalence is overlooked and its prevalence is low in Africa due to the use of low-sensitivity diagnostic methods and lack of correct diagnostic approach. A combination of microscopic and PCR method gives good detection rate of strongyloidiasis. Therefore, there is a need for using a combination of microscopic and molecular-based diagnostic methods to determine the true prevalence in Africa. Further research is also needed to break the transmission cycle and reduce the impacts of strongyloidiasis in the African population.

Data Availability

The data can be requested from Bahir Dar University (https://bdu.edu.et/node/74).

Conflicts of Interest

The author(s) declare(s) that they have no conflicts of interest.

Authors’ Contributions

All the authors acknowledged their active participation during gathering and screening of articles and critically reviewing this systematic review and meta-analysis.

References

[1] D. I. Grove, “Human strongyloidiasis,” Advances in Parasitol- ogy, vol. 38, pp. 251–309, 1996.
[2] R. W. Ashford, G. Barnish, and M. E. Viney, “Strongyloides fuelleborni kellyi: infection and disease in Papua New Guinea,” Parasitology Today, vol. 8, no. 9, pp. 314–318, 1992.
[3] A. Requena-Méndez, P. Chiodini, Z. Bisoﬁ, D. Buonfrate, E. Gotuzzo, and J. Muñoz, “The Laboratory Diagnosis and Follow Up of Strongyloidiasis: A Systematic Review,” PLoS Neglected Tropical Diseases, vol. 7, no. 1, p. e2002, 2013.
[4] Z. Bisoﬁ, D. Buonfrate, A. Montresor et al., “Strongyloides stercoralis: a plea for action,” PLoS Neglected Tropical Diseases, vol. 7, no. 5, 2013.
[5] WHO The world Health Organization, Soil-transmitted helminth infections. Fact sheet, 2016, September 2019 http:// www.who.int/intestinal_worms/en/.
[6] A. Amor, E. Rodriguez, J. M. Saugar et al., “High prevalence of Strongyloides stercoralis in school-aged children in a rural highland of North-Western Ethiopia: the role of intensive diagnostic work-up,” Parasites & Vectors., vol. 9, no. 1, p. 617, 2016.
[7] F. Schär, U. Trostdorf, F. Giardina et al., “Strongyloides stercoralis: global distribution and risk factors,” PLoS Neglected Tropical Diseases, vol. 7, no. 7, p. e2288, 2013.
[8] A. Olsen, L. van Lieshout, H. Marti et al., “Strongyloidiasis–the most neglected of the neglected tropical diseases?,” Transac- tions of the Royal Society of Tropical Medicine and Hygiene, vol. 103, no. 10, pp. 967–972, 2009.
[9] M. Viney and J. B. Lok, Strongyloides spp., The C. elegans Research Community, Ed., WormBook, 2007.
[10] D. I. Grove, “Strongyloidiasis: a conundrum for gastroenterologists,” Gut, vol. 35, no. 4, pp. 437–440, 1994.

[11] D. S. Nsagha, A. L. Njunda, N. J. C. Assob et al., “Intestinal parasitic infections in relation to CD4+ T cell counts and diarrhea in HIV/AIDS patients with or without antiretroviral therapy in Cameroon,” BMC Infectious Diseases, vol. 16, no. 1, 2015.

[12] H. L. Rotman, W. Yutanawiboonchai, R. A. Brigandi et al., “Strongyloides stercoralis: eosinophil-independent immune-mediated killing of third stage larvae in BALB/cByJ mice,” Experimental Parasitology, vol. 82, no. 3, pp. 267–278, 1996.

[13] B. M. Mandong and A. J. K. Madaki, “Missed diagnosis of schistosomiasis leading to unnecessary surgical procedures in Jos University Teaching Hospital,” Tropical Doctor, vol. 35, no. 2, pp. 96–97, 2005.

[14] R. G. de Kaminsky, “Evaluation of three methods for laboratory diagnosis of Strongyloides stercoralis infection,” The Journal of Parasitology, vol. 79, no. 2, pp. 277–280, 1993.

[15] T. Arakaki, M. Iwanaga, F. Kinjo, A. Saito, and T. Ikehishi, “Efficacy of Agar-Plate Culture in Detection of Strongyloides stercoralis Infection,” The Journal of Parasitology, vol. 76, no. 3, pp. 425–428, 1990.

[16] B. J. Pak, F. Vasquez-Camargo, E. Kalinichenko et al., “Development of a rapid serological assay for the diagnosis of strongyloidiasis using a novel diffusion-based biosensor technology,” PLoS Neglected Tropical Diseases, vol. 8, no. 8, 2014.

[17] F. M. de Paula, F. de Mello Malta, P. D. Marques et al., “Molecular diagnosis of strongyloidiasis in tropical areas: a comparison of conventional and real-time polymerase chain reaction with parasitological methods,” Memórias do Instituto Oswaldo Cruz, vol. 110, no. 2, pp. 272–274, 2015.

[18] T. Assefa, T. Woldemichael, and T. Seyoum, “Evaluation of the modified Baermann’s method in the laboratory diagnosis of Strongyloides stercoralis,” Ethiopian Medical Journal, vol. 29, no. 4, pp. 193–198, 1991.

[19] E. Dacal, J. M. Saugar, A. de Lucio et al., “Prevalence and molecular characterization of Strongyloides stercoralis, Giardia duodenalis, Cryptosporidium spp., and Blastocystis spp. isolates in school children in Cubal, Western Angola,” Parasites & Vectors, vol. 11, no. 1, p. 67, 2018.

[20] C. Bocanegra, S. Gallego, J. Mendioroz et al., “Epidemiology of Schistosomiasis and Usefulness of Indirect Diagnostic Tests in School-Age Children in Cubal, Central Angola,” PLOS Neglected Tropical Diseases, vol. 9, no. 10, p. e0004055, 2015.

[21] M. L. A. R. de Alegría, A. Nindia, M. Moreno et al., “Prevalence of Strongyloides stercoralis and Other Intestinal Parasite Infections in School Children in a Rural Area of Angola: A Cross-Sectional Study,” The American Journal of Tropical Medicine and Hygiene, vol. 97, no. 4, pp. 1226–1231, 2017.

[22] S. D. Karou, D. Sanou, D. Ouermi et al., “Enteric parasites prevalence at Saint Camille Medical Centre in Ouagadougou, Burkina Faso,” Asian Pacific Journal of Tropical Medicine, vol. 4, no. 5, pp. 401–403, 2011.

[23] J. Bopda, H. Nana-Djounga, J. Tenaguen et al., “Prevalence and intensity of human soil transmitted helminth infections in the Akanolenga health district (Centre region, Cameroon): are adult hosts contributing in the persistence of the transmission?,” Parasite Epidemiology and Control, vol. 1, no. 2, pp. 199–204, 2016.

[24] T. Kuete, F. L. S. Mvoa, T. Nkoa, R. M. Somo, and A. S. Ekobo, “Prevalence and risk factors of intestinal helminth and Protozoa infections in an urban setting of Cameroon: the case of Douala,” Am J Epidemiol Infect Dis, vol. 3, no. 2, pp. 36–44, 2015.

[25] S. L. Becker, N. Piraisoody, S. Kramme et al., “Real-time PCR for detection of Strongyloides stercoralis in human stool samples from Côte d’Ivoire: diagnostic accuracy, inter-laboratory comparison and patterns of hookworm co-infection,” Acta Tropica, vol. 150, pp. 210–217, 2015.

[26] D. Glinz, N. A. N’Guessan, J. Utzinger, and E. K. N’Goran, “High prevalence of Strongyloides stercoralis among school children in rural Côte d’Ivoire,” The Journal of Parasitology, vol. 96, no. 2, pp. 431–433, 2010.

[27] H. Z. Rayan, R. H. Soliman, and N. M. Galal, “Detection of Strongyloides stercoralis in fecal samples using conventional parasitological techniques and real-time PCR: a comparative study,” Parasitol United J., vol. 5, pp. 27–34, 2012.

[28] M. Roka, P. Goni, E. Rubio, and A. Clavel, “Intestinal parasites in HIV-seropositive patients in the continental region of Equatorial Guinea: its relation with socio-demographic, health and immune systems factors,” Transactions of the Royal Society of Tropical Medicine and Hygiene, vol. 107, no. 8, pp. 502–510, 2013.

[29] M. Roka, P. Goni, E. Rubio, and A. Clavel, “Prevalence of intestinal parasites in HIV-positive patients on the island of Bioko, Equatorial Guinea: its relation to sanitary conditions and socioeconomic factors,” Sci Total Environ., vol. 432, pp. 404–411, 2012.

[30] M. Abdi, E. Nibret, and A. Munshea, “Prevalence of intestinal helminthic infections and malnutrition among school-children of the Zeg Peninsula, northwestern Ethiopia,” Journal of Infection and Public Health, vol. 10, no. 1, pp. 84–92, 2017.

[31] J. M. Ramos, N. Rodríguez-Valero, G. Tisiano et al., “Different profile of intestinal protozoa and helminthic infections among patients with diarrhea according to age attending a rural hospital in southern Ethiopia,” Tropical Biomedicine, vol. 31, no. 2, pp. 392–397, 2014.

[32] A. Zeynudin, K. Hemalatha, and S. Kannan, “Prevalence of opportunistic intestinal parasitic infection among HIV infected patients who are taking antiretroviral treatment at Jimma Health Center, Jimma, Ethiopia,” European Review for Medical and Pharmacological Sciences, vol. 17, no. 4, pp. 513–516, 2013.

[33] S. Assefa, B. Erko, G. Medhin, Z. Assefa, and T. Shimelis, “Intestinal parasitic infections in relation to HIV/AIDS status, diarrhea and CD4 T-cell count,” BMC Infectious Diseases, vol. 9, no. 1, 2009.

[34] T. Wegayehu, T. Tsalla, B. Seifu, and T. Teklu, “Prevalence of intestinal parasitic infections among highland and lowland dwellers in Gamo area, South Ethiopia,” BMC Public Health, vol. 13, no. 1, 2013.

[35] K. Huruy, A. Kassu, A. Mulu et al., “Intestinal parasitosis and shigellosis among diarrheal patients in Gondar Teaching Hospital, northwest Ethiopia,” BMC Research Notes, vol. 4, no. 1, 2011.

[36] D. Gedle, B. Gelaw, D. Muluye, and M. Mesele, “Prevalence of malnutrition and its associated factors among adult people living with HIV/AIDS receiving anti-retroviral therapy at Butajira Hospital, southern Ethiopia,” BMC Nutrition., vol. 1, no. 1, p. 5, 2015.
[37] B. Adera, G. Alem, M. Yimer, and Z. Herrador, “Epidemiology of soil-transmitted helminths, Schistosoma mansoni, and haematocrit values among schoolchildren in Ethiopia,” *Journal of Infection in Developing Countries*, vol. 7, no. 3, pp. 253–260, 2013.

[38] A. Derso, E. Nibret, and A. Munsha, “Prevalence of intestinal parasitic infections and associated risk factors among pregnant women attending antenatal care center at Felege Hiwot Referral Hospital, Northwest Ethiopia,” *BMC Infectious Diseases*, vol. 16, no. 1, p. 530, 2016.

[39] S. Fekadu, K. Taye, W. Teshome, and S. Asnake, “Prevalence of parasitic infections in HIV-positive patients in southern Ethiopia: a cross-sectional study,” *Journal of Infection in Developing Countries*, vol. 7, no. 11, pp. 868–872, 2013.

[40] A. Abate, B. Kibret, E. Bekalu et al., “Cross-Sectional Study on the Prevalence of Intestinal Parasites and Associated Risk Factors in Teda Health Centre, Northwest Ethiopia,” *ISRN Parasitology*, vol. 2013, Article ID 757451, 5 pages, 2013.

[41] G. Alemu, D. Alegin, and A. Abossie, “Prevalence of opportunistic intestinal parasites and associated factors among HIV patients while receiving ART at Arba Minch Hospital in southern Ethiopia: a cross-sectional study,” *Ethiopian Journal of Health Sciences*, vol. 28, no. 2, pp. 147–156, 2018.

[42] Z. Teklemariam, D. Abate, H. Mitiku, and Y. Dessie, “Prevalence of intestinal parasitic infection among HIV positive persons who are naive and on antiretroviral treatment in Hiwot Fana Specialized University Hospital, eastern Ethiopia,” *ISRN AIDS*, vol. 2013, Article ID 324329, 6 pages, 2013.

[43] L. Legesse, B. Erko, and A. Hailu, “Current status of intestinal Schistosomiasis and soil-transmitted helmintiasis among primary school children in Adwa Town, Northern Ethiopia,” *Ethiopian Journal of Health Development*, vol. 24, no. 3, 2011.

[44] A. W. Hailu, S. Selassie, Y. Merid, A. A. Gebru, Y. Y. Ayene, and M. K. Asefa, “The case control studies of HIV and intestinal parasitic infections rate in active pulmonary tuberculosis patients in Woldia General Hospital and Health Center in North Wollo, Amhara region, Ethiopia,” *International Journal of Pharma Sciences*, vol. 5, no. 3, pp. 1092–1099, 2015.

[45] L. A. Nyantke, M. Legesse, M. Belay et al., “Intestinal parasitic infections among under-five children and maternal awareness about the infections in Shessa Kekele, Wondo Genet, Southern Ethiopia,” *Ethiopian Journal of Health Development*, vol. 24, no. 3, pp. 185–190, 2011.

[46] B. Chala, “A retrospective analysis of the results of a five-year (2005–2009) parasitological examination for common intestinal parasites from Bale-Robe Health Center, Robe town, southeastern Ethiopia,” *ISRN Parasitology*, vol. 2013, Article ID 694731, 7 pages, 2013.

[47] N. P. M’boundoukwé, E. Kendjo, D. P. Mawili-Mboumba et al., “Prevalence of and risk factors for malaria, filariasis, and intestinal parasites as single infections or co-infections in different settlements of Gabon, Central Africa,” *Infectious Diseases of Poverty*, vol. 7, no. 1, p. 6, 2018.

[48] S. Janssen, S. Hermans, M. Knap et al., “Impact of anti-retroviral treatment and cotrimoxazole prophylaxis on helmint infections in HIV-infected patients in Lambaréné, Gabon,” *PLOS Neglected Tropical Diseases*, vol. 9, no. 5, 2015.

[49] P. Mbounou, P. Mboumba, F. Mondouo, M. Kombila, and M. Akotet, “Prevalence of soil-transmitted helminths and intestinal Protozoa in shanty towns of Libreville, Gabon,” *International Journal of TROPICAL DISEASE & Health*, vol. 20, no. 3, pp. 1–9, 2016.

[50] D. Adu-Gyasi, K. P. Asante, M. T. Frempong et al., “Epidemiology of soil transmitted helmint infections in the middle-belt of Ghana, Africa,” *Parasite Epidemiology and Control*, vol. 3, no. 3, p. e00071, 2018.

[51] B. Nkrumah and S. B. Nguah, “Giardia lamblia: a major parasitic cause of childhood diarrhoea in patients attending a district hospital in Ghana,” *Parasites & Vectors*, vol. 4, no. 1, 2011.

[52] A. O. Forson, I. Arthur, M. Olu-Taiwo, K. K. Glover, P. J. Pappoe-Ashong, and P. F. Ayeh-Kumi, “Intestinal parasitic infections and risk factors: a cross-sectional survey of some school children in a suburb in Accra, Ghana,” *BMJ Research Notes*, vol. 10, no. 1, p. 485, 2017.

[53] N. J. Yatch, J. C. Rayner, A. Turpin et al., “Malaria and intestinal helmint infection among pregnant women in Ghana: prevalence and risk factors,” *The American Journal of Tropical Medicine and Hygiene*, vol. 80, no. 6, pp. 896–901, 2009.

[54] Y. Sam, F. J. Edzream, E. H. Frimpong, A. K. Ako, and K. Appiah-Kubi, “Prevalence of soil-transmitted helminths among school pupils in the upper east region of Ghana using direct wet mount technique and formol-ether concentration technique,” *IJTDH*, vol. 32, no. 3, pp. 1–9, 2018.

[55] L. J. Cunningham, J. Oodoom, D. Pratt et al., “Expanding molecular diagnostics of helmintihiasis: piloting use of the GPLN platform for surveillance of soil transmitted helmintiasis and schistosomiasis in Ghana,” *PLOS Neglected Tropical Diseases*, vol. 12, no. 1, 2018.

[56] J. M. Kagira, N. Maina, N. Jenga, S. M. Karanja, S. M. Karori, and J. M. Ngotho, “Prevalence and types of coinfections in sleeping sickness patients in Kenya (2000/2009),” *Journal of Tropical Medicine*, vol. 2011, Article ID 248914, 6 pages, 2011.

[57] J. L. Walton, B. T. Stewart, L. Sangaré et al., “Prevalence and correlates of helmint co-infection in Kenyan HIV-1 infected adults,” *PLOS Neglected Tropical Diseases*, vol. 4, no. 3, p. e644, 2010.

[58] M. B. Arndt, G. John-Stewart, B. A. Richardson et al., “Impact of helmint diagnostic test performance on estimation of risk factors and outcomes in HIV-positive adults,” *PLOS One*, vol. 8, no. 12, 2013.

[59] L. Meurs, A. M. Polderman, N. V. S. Vinkeles Melchers et al., “Diagnosing polyparasitism in a high-prevalence setting in Beira, Mozambique: detection of intestinal parasites in fecal samples by microscopy and real-time PCR,” *PLOS Neglected Tropical Diseases*, vol. 11, no. 1, 2017.

[60] B. Z. Cerveja, R. M. Tucuzo, A. C. Madureira et al., “Prevalence of Intestinal Parasites Among HIV Infected and HIV Uninfected Patients Treated at the 1st De Maio Health Centre in Maputo, Mozambique,” *EC Microbiology*, vol. 9, no. 6, pp. 231–240, 2017.

[61] M. C. Chukwuoma, I. M. Ekejindu, N. R. Agbakoba, D. A. Ezegwuna, I. C. Anaghalu, and D. C. Nwosu, “The prevalence and risk factors of geohelminth infections among primary school children in Ebenebe town, Anambra state, Nigeria,” *Middle-East J Sci Res.*, vol. 4, no. 3, pp. 211–215, 2009.

[62] A. C. Uhuo, O. O. Odikamnor, and O. C. Ani, “The incidence of intestinal nematodes in primary school children in Ezza North local government area, Ebonyi state Nigeria,” *Advances in Applied Science Research*, vol. 2, no. 5, pp. 257–262, 2011.
[100] F. Schär, P. Odermatt, V. Khieu et al., “Evaluation of real-time PCR for Strongyloides stercoralis and hookworm as diagnostic tool in asymptomatic schoolchildren in Cambodia,” *Acta Tropica*, vol. 126, no. 2, pp. 89–92, 2013.

[101] L. A. Pocaterra, G. Ferrara, R. Peñaranda et al., “Improved Detection of Strongyloides stercoralis in Modified Agar Plate Cultures,” *The American Journal of Tropical Medicine and Hygiene*, vol. 96, no. 4, pp. 863–865, 2017.

[102] V. Khieu, F. Schär, A. Forrer et al., “High prevalence and spatial distribution of Strongyloides stercoralis in rural Cambodia,” *PLoS Neglected Tropical Diseases*, vol. 8, no. 6, p. e2854, 2014.

[103] A. Forrer, V. Khieu, P. Vounatsou et al., “Strongyloides stercoralis: Spatial distribution of a highly prevalent and ubiquitous soil-transmitted helminth in Cambodia,” *PLoS Neglected Tropical Diseases*, vol. 13, no. 6, p. e0006943, 2019.

[104] Y. Terefe, K. Ross, and H. Whiley, “Strongyloidiasis in Ethiopia: systematic review on risk factors, diagnosis, prevalence and clinical outcomes,” *Infectious Diseases of Poverty*, vol. 8, no. 1, p. 53, 2019.

[105] P. A. B. L. O. P. YORI, C. A. R. Y. N. BERN, C. E. S. A. R. B. A. N. D. A. CHAVEZ et al., “SEROEPIDEMIOLOGY OF STRONGYLOIDIASIS IN THE PERUVIAN AMAZON,” *The American Journal of Tropical Medicine and Hygiene*, vol. 74, no. 1, pp. 97–102, 2006.

[106] FAO, IFAD, UNICEF, WFP, and WHO, *The State of Food Security and Nutrition in the World 2019*. Safeguarding against economic slowdowns and downturns, FAO, Rome, 2019, https://www.unicef.org/media/55921/file/SOFI-2019.

[107] A. Forrer, V. Khieu, F. Schär et al., “Strongyloides stercoralis is associated with significant morbidity in rural Cambodia, including stunting in children,” *PLOS Neglected Tropical Diseases*, vol. 11, no. 10, p. e0005685, 2017.

[108] L. Gétaz, R. Castro, P. Zamora et al., “Epidemiology of Strongyloides stercoralis infection in Bolivian patients at high risk of complications,” *PLOS Neglected Tropical Diseases*, vol. 13, no. 1, p. e0007028, 2019.

[109] E. Ahmadpour, M. A. Ghanizadaeghan, A. Razavi et al., “Strongyloides stercoralis infection in human immunodeficiency virus-infected patients and related risk factors: a systematic review and meta-analysis,” *Transboundary and Emerging Diseases*, vol. 66, no. 6, pp. 2233–2243, 2019.

[110] WGO World Gastroenterology Organization, 2004, *Practice guideline management of strongyloidiasis*. https://www.worldgastroenterology.org/UserFiles/file/guidelines/management-of-strongyloidiasis-english-2004.pdf.

[102] V. Khieu, F. Schär, A. Forrer et al., “High prevalence and spatial distribution of Strongyloides stercoralis in rural Cambodia,” *PLoS Neglected Tropical Diseases*, vol. 8, no. 6, p. e2854, 2014.

[103] A. Forrer, V. Khieu, P. Vounatsou et al., “Strongyloides stercoralis: Spatial distribution of a highly prevalent and ubiquitous soil-transmitted helminth in Cambodia,” *PLoS Neglected Tropical Diseases*, vol. 13, no. 6, p. e0006943, 2019.

[101] L. A. Pocaterra, G. Ferrara, R. Peñaranda et al., “Improved Detection of Strongyloides stercoralis in Modified Agar Plate Cultures,” *The American Journal of Tropical Medicine and Hygiene*, vol. 96, no. 4, pp. 863–865, 2017.

[102] V. Khieu, F. Schär, A. Forrer et al., “High prevalence and spatial distribution of Strongyloides stercoralis in rural Cambodia,” *PLoS Neglected Tropical Diseases*, vol. 8, no. 6, p. e2854, 2014.

[103] A. Forrer, V. Khieu, P. Vounatsou et al., “Strongyloides stercoralis: Spatial distribution of a highly prevalent and ubiquitous soil-transmitted helminth in Cambodia,” *PLoS Neglected Tropical Diseases*, vol. 13, no. 6, p. e0006943, 2019.

[104] Y. Terefe, K. Ross, and H. Whiley, “Strongyloidiasis in Ethiopia: systematic review on risk factors, diagnosis, prevalence and clinical outcomes,” *Infectious Diseases of Poverty*, vol. 8, no. 1, p. 53, 2019.