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Chapter

Soil-Transmissible Helminths Infections; Diagnosis, Transmission Dynamics, and Disease Management Strategies in Low-and Middle-Income Countries

James-Paul Kretchy

Abstract

Soil-transmissible helminths (STHs) infections are the most common sanitation-related public health problems among people living in poor settlements of tropical and sub-tropical regions in low- and middle-income countries (LMICs). Though available data suggest the occurrence of disease in adults, children of school-going age bear the greatest burden, affecting their cognitive development and physical growth. The characteristic high levels of poverty, poor environmental hygiene, open defecation practices, and inadequate sanitation and waste management systems, expose residents to the risks of STH infections. Walking bare-footed, inappropriate hand hygiene behaviour, and the unavailability/improper use of personal protective equipment (PPE) can impact transmission risks in endemic communities and among occupational risk groups. These have to be properly investigated, managed, and appropriate interventions communicated to decision-makers.

Keywords: control, diagnostics, exposure, soil-transmitted helminths, low-and middle-income countries, personal protective equipment

1. Introduction

1.1 Background information and disease burden

Soil-transmissible helminths (STHs) refer to the intestinal worms infecting humans that are transmissible through faecal contaminated soil. Infections caused by STHs are widely endemic and constitute one of the major public health problems, particularly in African, South American, and Asian LMICs [1]. The geographical distribution of parasites causing these infections is known to be influenced by prevailing environmental and climatic conditions. For example, poor environmental sanitation and hygiene conditions in tropical and sub-tropical regions are major determinants of STHs. The WHO estimates that about 2.5 billion people globally, currently have no
access to improved sanitation whilst close to 1.1 billion others practice open defecation [2]. Furthermore, the inequalities in socio-economic status of human populations at risk, particularly regarding access to clean water and sanitation, housing, and the access to anti-helminthic treatment, impact the observed epidemiological distribution of STH infections [3]. The transmission is by human exposures to the infective stages, either by direct skin penetration or through ingestion, which can lead to serious illness, though infections remain asymptomatic in the majority of cases with light-intensity infections. Laboratory diagnosis is the gold standard in confirming STH infections, since clinical symptoms present as non-specific gastrointestinal diseases and among persons with high intensity of infection.

The current global disease burden suggests that nearly two (2) billion people are infected, with over 80% of the disease burden found in tropical and sub-tropical regions of LMICs [4]. An estimated 870 million children live in areas of high prevalence in Africa, South Asia, and South America. The diseases are attributed to the four most prevalent STHs namely, *Ascaris lumbricoides*, *Trichuris trichiura*, or the hookworms (*Ancylostoma doudenale/*Necator americanus), infecting approximately 807–1121 million, 604–795 million, and 576–740 million people, respectively. *Strongyloides stercoralis*, which is the least prevalent and most neglected STH species, is responsible for an estimated 30–100 million infections globally. With the specific emphasis of the disease burden in LMICs, previous studies have found that unlike in Ghana (2.1%), *Ascaris lumbricoides* have the widest distribution reported in Nigeria (25.4%), Cameroon (30.8%), Equatorial Guinea (38.8%), and Congo (32.2%). In South America, infections with *Ascaris lumbricoides* is less widely dispersed in Ecuador (35.8%), Colombia (26.0%), and Venezuela (28.4%) compared with Asian LMICs like in the Philippines (33.6%), Afghanistan (36.0%), Malaysia (41.7%), and Bangladesh (38.4%). The hookworm infections with *Ancylostoma doudenale/*Necator americanus, remain common throughout African LMICs like Ghana (52.9%), in addition to the Asian LMICs, Malaysia (21.0%), Bangladesh (22.3%), Nepal (30.7%), and Papua New Guinea (60.6%). The prevalence of *Trichuris trichiura* infections in Asian LMICs like Malaysia (49.9%), and the Philippines (45.5%), as well as in the South American LMIC, Venezuela (28.4%) is more than that reported in the African LMIC Ghana, (0.8%).

It is worth considering that in addition to the single infections caused, multiple-species infections in a single individual are also common, and taken together, can cause considerable global health impacts and decrease economic productivity in vulnerable populations of many LMICs [2, 5]. The epidemiological patterns of the disease burden require consolidated efforts by governments, communities, and healthcare institutions to adopt context-specific public health interventions that would see a reduction in the rates of STH infections, if not to eliminate or completely eradicate them. Even though these infections have been reported among specific risk groups like adult food vendors [6] and sanitation workers [7] in African LMICs, the greatest burden is confirmed in children of school-going age, affecting their cognitive development and physical growth [8]. For example, an estimated 270 million preschool children and over 568 million school-going children currently have infections that require anti-helminthic treatment and prevention interventions.

The available literature on transmission conditions of STHs, diagnostic techniques used to identify the species variety, risk factors to infections, and suggested public health interventions to reduce the risk of infection in exposed populations are inadequately published and are mostly presented in journal articles. This chapter, therefore, sought to conduct a narrative description of these aspects, plus present a case
study of STH infections in an occupational risk-group in an African LMIC, to provide context-based recommendations on how STHs can be prevented and controlled in vulnerable populations living in such settings.

2. Methodology

The narrative review approach was used to draft this chapter. Information was retrieved from the internet-based search for original articles and reviews published between the years 2000 and 2021, using PubMed and Google scholar portals, and from textbooks. The keywords used for the literature search and inclusion criteria were ‘control, diagnostics, exposure, soil-transmitted helminths, low-and middle-income countries, and personal protective equipment’. In-text references have been cited appropriately and full references are provided in the bibliography section.

3. Literature review

3.1 Transmission conditions and risk factors to STH infections in LMICs

Studies in Ghana and other LMICs have shown that residents in rural and peri-urban communities have higher risks for STH infections than in urban communities because of the higher proportions of poverty, poor environmental hygiene, inadequate sanitation, open defecation, and inadequate waste management systems [9, 10]. These factors perpetuate the continued existence of STHs in such settings. The infective stages of STHs persist for longer periods in human or animal faecal polluted environments and can survive a wide range of physical and chemical conditions, thereby, posing the highest disease risks to community members, particularly in pre-school children or those of school-going age, compared with other biological agents like bacteria and viruses [11, 12]. The adequate warmth and moisture in many tropical and sub-tropical LMICs also favour the survival of STH eggs and increase the risk of transmission to people living in endemic areas [13]. Researchers have also reported the persistence of STH eggs in salty beaches in Brazil [14], and Portugal [15], due to faecal contamination of the beach soil.

According to the WHO [16] although the human threadworm (*Strongyloides stercoralis*) is an important member of the STHs, it is the least prevalent. The most important STH species that infect people are the human roundworm (*Ascaris lumbricoides*), the human whipworm (*Trichuris trichiura*) and the two hookworm species (*Necator americanus* and *Ancylostoma duodenale*). These groups of STHs do not require intermediate hosts in their life cycle. Rather, the adult helminths lay eggs that hatch into larvae, grow, and then develop into adult worms inside the gastrointestinal tract of humans. The major mode of transmission is through direct faecal-oral ingestion of the eggs/ova (for *Ascaris lumbricoides*, *Trichuris trichiura*, and the hookworm, *Ancylostoma duodenale*) [17]. The *Necator americanus* is rather transmitted through direct penetration of the larvae through exposed parts of the body [18]. Government agencies and other stakeholders in the health sector of affected LMICs need to ensure the implementation of Public health intervention measures that target the blocking of the transmission chains, such as improved water, sanitation and hygiene (WASH) uptake, prevent the establishment of disease, and to improve the quality of lives, particularly of children and other occupational risk groups.
3.2 Clinical and laboratory diagnosis of STH infections

Though clinical diagnoses of STH infections are based on the signs and symptoms accompanying the disease after the establishment of an infection, infected persons usually remain clinically asymptomatic, and the diseases rarely cause mortality. When present, clinical symptoms may include non-specific gastrointestinal symptoms, such as acute abdominal pain, diarrhoea or intestinal obstruction. Chronic symptoms may present as iron-deficiency anaemia, malnutrition, retarded growth, cognitive impairment, particularly in children, and pre-term delivery, low-birth weight babies, and impaired lactation in pregnant/post-natal women. These clinical manifestations as well as self-reported cases, need to be confirmed by identifying infective stages like eggs, ova, or larvae in bowel contents collected from suspected patients with clinical illness or from asymptomatic persons.

Laboratory diagnosis for confirmation of STH infections can be done by using diverse methods with varying sensitivity and specificity [19–21]. The two most effective methods are direct parasitological, using microscopy (i.e., sedimentation concentration, McMaster, Kato Katz, FLOTAC) and molecular methods (i.e., polymerase chain reaction). The different diagnostic methods, STH detected, usefulness, and disadvantages are summarised in Table 1. Culture techniques and serological assays are less preferred methods in STH infection diagnosis, compared with microscopy and molecular techniques. The choice of a particular diagnostic method requires paying considerable attention to factors such as rapidity of obtaining test results, availability of infrastructure, cost of assay, ease of performance, and level of application in the field (Table 1). Other conditions such as proper training of laboratory personnel and strict compliance to quality control or quality assurance procedures could enhance the performance of diagnostic methods to confirm STHs. Confirmed diagnosis helps to ascertain individual infection status, and to estimate the incidence, prevalence, and intensity of infections among populations at risk. The outcomes of diagnosis can again be used to evaluate the effectiveness of parasite control measures like parasite clearance, the reduction in incidence or prevalence, and the intensity of infections. The benefit of laboratory findings is also to provide context-based policy guidance on the frequency of anti-helminthic treatment or prophylactic therapy in affected geographical areas.

3.3 The specific case of STH infections in an African LMIC

A longitudinal study conducted by Kretchy et al. [7], showed 4.3% incidence rate and low intensity of infections with the STH, *Trichuris trichiura* (*T. trichiura*) among waste handlers in a large coastal peri-urban settlement in Southern Ghana, six months post-treatment with albendazole (400 mg single oral dosage). This incidence rate for *T. trichiura* was, however, higher compared with the national average in an adult population (1.2%) and among non-school going children (0.8%) in endemic communities in Kintampo, Ghana [22, 23]. This could mean that waste handlers were at higher risk of infection with *T. trichiura* compared with the adult population of an endemic area in Ghana due to their occupational exposures. However, a similar study conducted in endemic communities in India by Narain et al. [24] among a group of teenagers found a higher incidence of infection with *T. trichiura* (43.6%), six months post-treatment with albendazole (400 mg). The most common health complaints following infections with *T. trichiura* include mainly intestinal, such as diarrhoea and abdominal pain [25]. Whilst heavy infections in adults have been found to cause
<table>
<thead>
<tr>
<th>Diagnostic method for STH</th>
<th>S. stercoralis</th>
<th>A. lumbricoides</th>
<th>T. trichiura</th>
<th>N. americanus</th>
<th>A. duodenale</th>
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<tbody>
<tr>
<td>Direct wet preparation/direct microscopy</td>
<td>√</td>
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<tr>
<td><strong>Usefulness</strong></td>
<td>Rapid, inexpensive, and time saving</td>
<td>Low sensitivity, semi-quantitative, not often used in control programs</td>
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<td>Kato–Katz</td>
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<tr>
<td><strong>Usefulness</strong></td>
<td>WHO &quot;gold standard,&quot; quantification of STH eggs, high sensitivity, minimal infrastructure requirement, ability to stratify infection intensities</td>
<td>Requires fresh faecal specimen</td>
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<td>Formol-ether concentration</td>
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<tr>
<td><strong>Usefulness</strong></td>
<td>Rapid, high sensitivity, Both fresh and preserved faecal specimens can be used, laboratory-acquired infection from faecal pathogens reduced</td>
<td>Rapid centrifugation inactivates infective stages, only qualitative, cannot be performed in laboratories with minimal infrastructure</td>
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<td>Zinc sulphate flotation</td>
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<tr>
<td><strong>Usefulness</strong></td>
<td>Detects eggs of light intensity T. trichiura in faeces, less time consuming compared with other floatation methods</td>
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<td>Saturated sodium chloride floatation</td>
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<td><strong>Usefulness</strong></td>
<td>Cost effective, useful in field surveys</td>
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<td>FLOTAC</td>
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<tr>
<td><strong>Usefulness</strong></td>
<td>Counting STH eggs in both human and veterinary faecal sample, less time consuming, highly sensitive, precise, accurate</td>
<td>Not useful in resource-limited settings, requires well-trained staff, uses larger amount of faecal specimen compared with Kato–Katz</td>
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<tr>
<td>McMaster</td>
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<tr>
<td><strong>Usefulness</strong></td>
<td>High sensitivity, fast and accurate results</td>
<td>Requires the use of a counting chamber which might not be readily available in resource-limited settings</td>
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<tr>
<td>Diagnostic method for STH</td>
<td>S. stercoralis</td>
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<td>Antigen detection (ELISA)</td>
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<td>Antibody detection (ELISA)</td>
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<td>Agar plate culture / Baermann</td>
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<td>Harada-Mori</td>
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<td>Molecular (PCR)</td>
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</table>

√: STH detected, –: limited or not good detection of STH, ELISA: Enzyme-linked immunosorbent assay, PCR: Polymerase chain reaction, NI: None identified [19–21].

Table 1. A summary of STH diagnostic methods, STH detected, usefulness, and disadvantages.
iron-deficiency anaemia [26], the light intensity infections recorded among the waste handlers may not result in this health outcome. Nevertheless, waste handlers who were infected with *T. trichiura* may serve as important reservoirs for the continued transmission of the STH among waste handlers, immediate family members and the entire peri-urban community as a whole. The findings from the study also indicated that STH infections were correlated with the type of waste handling activity performed, and that waste handlers who did not use the PPE gloves were about six times more likely to have STH infections compared to those who used gloves. This result has consolidated the knowledge on the importance of hands in the transmission of STH infections and the need to wear PPE to prevent the direct exposure of the bare hand to faecal contaminated soils/environments.

### 3.4 Public health interventions to reduce the risk of STH in exposed populations

In endemic populations, the risk of acquiring STH infections could be all year round however, several factors can predispose specific groups of persons to become susceptible. Specific risk factors in pre-school and children of school-going age to STH infections include having long or untrimmed fingernails, failure to wash hands before meals, walking bare-footed, nail-biting, and thumb-sucking habits. School-going children in particular, are more prone to STH infections when playing in unpaved, soil-infested school lawns. In communities, where tube-well rather than treated tap-water is used as the drinking water source, pre-school or non-school-going children become significantly vulnerable, because of the likelihood of faecal contamination from nearby latrines, seepage, or run-off water carrying faecal excrements from open defecation practices [27].

Practicing the appropriate public health intervention measures can reduce the exposure to the risk factors to STH infections in the environment and prevent disease occurrence. These can be achieved by preventive treatment with anti-helminthic drugs, adequate sanitation, and good environmental and personal hygiene practices, and by using appropriate PPE. Health education, change in health behaviour and periodic training among occupational risk groups may also be necessary preventive steps in reducing disease risks among persons living in endemic communities in resource-limited settings of African, Asian, and South American tropical, and subtropical LMICs.

The use of preventive anti-helminthic drugs is the current global strategy in controlling STH infections in at-risk populations [28]. In endemic countries like Ghana, albendazole (400 mg) and mebendazole (500 mg) are the anti-helminthic drugs of choice for the treatment against STH infections [29]. Albendazole and mebendazole have undergone extensive safety and efficacy testing and have been used in millions of people globally with only few and minor side effects [30]. Both drugs are effective broad-spectrum anti-helminthics, inexpensive and are easily administered by trained non-medical personnel. However, unlike mebendazole, albendazole (400 mg) is administered as a single oral dosage, which makes it easier to monitor treatment by direct observation by the researcher [16, 31]. The problem with preventive treatment with anti-helminthic drugs to at-risk populations is the inability to prevent re-infection after a short period of between three and six months [32, 33].

Other measures like proper sanitation and good personal hygiene practices are equally essential to reduce risk factors to STH infections. Good hygiene practices could also reduce the growth of other biological agents, in addition to STHs, on the hands of persons exposed to faecal contaminated soil. Wearing appropriate PPE
during food vending or waste handling, and using footwear in school-going children may serve as barriers to prevent direct physical contact with the infective stages and reduce transmission risks.

Public health education and health promotion activities about keeping healthy behaviours like handwashing with soap after playing in the soil, after engaging in waste handling activities or after defecation and before eating may help to reduce transmission and re-infection rates due to STHs. Receiving periodic training about the use of appropriate PPE may also be necessary preventive steps in reducing disease risks among occupational risk groups like food vendors and waste handlers. These interventions, in addition to the use of anti-helminthic drugs, are necessary steps needed to reduce risk factors to STH infections.

It is necessary for the appropriate authorities and policymakers in endemic areas of LMICs including governments, employers, district, and local health authorities to provide appropriate and suitable PPE, replace old and worn out PPE in occupational risk groups, and also provide sufficient sanitation and hygiene facilities, such as toilets, soap, and water, and supervise their use in basic schools and poor settlements. Community members in endemic areas must be encouraged to undergo periodic medical screening and participate in deworming exercises at least once in every six months.

4. Conclusion and recommendations

Vulnerable populations particularly children and occupation risk groups in African, Asian, and South American LMICs, are predominantly faced with the hazards of STH infections. Although the burden of disease is quite high in African LMICs like Ghana and Nigeria, the highest burden of infection from hookworms, *Trichuris trichiura*, and *Ascaris lumbricoides* was reported in Asia. The high endemticity of infection in such settings and populations has huge socio-economic and developmental consequences for those infected. The ability of healthcare systems to promote strategies to block the transmission pathways, prevent infection and reduce complications arising from associated diseases is critical. Stakeholders in government and private agencies, as well as employers of occupation risk groups, need to invest adequate funds, infrastructure, and resources to support efforts in diagnosis, treatment and evaluation of WASH interventions that can mitigate the infection burden in LMICs.

It is important for future surveillance programs in the control of STHs, to consider and adopt more effective interventions that would integrate highly sensitive and specific diagnostic techniques like the polymerase chain reaction rather than microscopy-based methods so that laboratories can detect light-intensity STH infections even in areas of low endemicity. This would enable public health systems to implement appropriate curative or preventive measures against the transmission of STHs, particularly in vulnerable populations.

Acknowledgements

The Public Health (PH) Unit of the School of Medicine and Health Sciences (SMHS), Central University (CU) is greatly appreciated for its support in providing logistics and office space to conduct the narrative review in this chapter.
Conflict of interests

The author declares no conflict of interests in this chapter.

List of abbreviations

DNA        Deoxyribonucleic Acid
ELISA      Enzyme-linked Immunosorbent Assay
LMIC       Low-and Middle-Income Country
PCR        Polymerase Chain Reaction
PPE        Personal Protective Equipment
STH        Soil-transmissible Helminth
WHO        World Health Organisation

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