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POTENTIAL CONTRIBUTION OF ADULT POPULATIONS TO THE MAINTENANCE OF SCHISTOSOMIASIS AND SOIL-TRANSMITTED HELMINTH INFECTIONS IN THE SIAVONGA AND MAZABUKA DISTRICTS OF ZAMBIA

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Summary. A majority of Zambian children live in impoverished communities that lack safe water and proper sanitation, exposing them to urogenital and intestinal helminths. Efforts to mitigate this plight have been implemented through mass drug administration aimed at deworming school-age and under-five children against schistosomiasis and soil-transmitted helminths. However, the disease status of adults living in the same communities as the treated children remains unknown. The aim of this study was to describe the potential contribution of infected adult populations to the transmission of these infections in southern Zambia. A cross-sectional study was conducted in April and May 2013 as part of baseline survey for a larger study in Mazabuka and Siavonga Districts. Stool and urine samples of 2829 adults from five catchment areas were collected and processed using Kato-Katz and urine filtration methods, respectively. Adults from Siavonga had a 13.9% combined prevalence of *Schistosoma haematobium* and *S. mansoni*, and 12.1% combined prevalence of *Ascaris lumbricoides* and hookworm. There was no *S. mansoni* in Mazabuka, and only a 5.3% prevalence of *S. haematobium* and 7.4% combined prevalence of *A. lumbricoides* and hookworm. Additionally, no *Trichuris trichiura* infections were observed in the two districts. Despite most of these infections being categorized as light intensity, heavy infection intensities were also found for all four parasite species. If this infected adult population is left untreated, the possibility of it acting as a reservoir of infections and ultimately transmitting the infections to treated children remains. Therefore, there is need to consider alternative treatment strategies that incorporate adults, thereby reducing the risk of contaminating the environment and perpetuating transmission to children.

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Introduction

Zambia is amongst the many developing countries in Africa with a marked population of children living in low socioeconomic communities that lack access to safe water and sanitation (Chimbari *et al.*, 2003; Halwindi *et al.*, 2010; Salam *et al.*, 2014). In such impoverished settings, children are more susceptible to urogenital and intestinal helminth infections when compared with any other age group (Hotez *et al.*, 2006; Tchuem Tcuenté, 2012). This vulnerability is particularly heightened by their regular contact with snail-infested (*Bulinus globosus* or *Biomphalaria* spp.) water bodies or faeces-contaminated soils (Mubila & Rollinson, 2002; Chimbari *et al.*, 2003). Infected children will eventually develop chronic disease conditions, including multi-organ damage, malnutrition, micronutrient deficiencies, stunted growth and impaired cognitive development, as well as reduced physical fitness (Bethony *et al.*, 2006; Njenga *et al.*, 2011; Tchuem Tcuenté, 2012; Mugono *et al.*, 2014; Salam *et al.*, 2014). These morbidities are principally instigated by water-borne *S. haematobium* and *S. mansoni*, which cause urogenital and intestinal schistosomiasis, respectively. Similarly, these morbidities also result from the triad of soil-transmitted helminths (STH): hookworm, *Ascaris lumbricoides* and *Trichuris trichiura* (Ekundayo *et al.*, 2007; Tchuem Tcuenté, 2012; Mugono *et al.*, 2014). Infected individuals generally encounter these parasites early in their childhood and some infections may remain subclinical until adulthood, when the most severe clinical manifestations occur, especially with heavy infections (Njenga *et al.*, 2011; Tchuem Tcuenté, 2012; Mugono *et al.*, 2014).

In endemic areas school-age children have the highest infection intensities, and this gradually reduces with age, with the exception of hookworm, which inversely peaks in adulthood (Bethony *et al.*, 2002; Tchuem Tcuenté, 2012; Mugono *et al.*, 2014). High prevalence rates in children are frequently used as a measure of recent infections and also indicate active foci of transmission (Hira, 1969). However, from a public health perspective, any infected person, regardless of age, represents a source of infection to the rest of the community due to the parasitic eggs they discharge in their faeces and urine (WHO, 2002). Yet mass drug administration against schistosome and STH infections specifically promotes the deworming of under-five and school-age children at health centres and schools, respectively (Halwindi *et al.*, 2010; Mwandawiro *et al.*, 2013; Salam *et al.*, 2014; Shawa *et al.*, 2014). This approach has been previously shown to provide externality benefits to the untreated persons, especially adults that live in the same community as the treated children (Njenga *et al.*, 2011). However, there is very little information on the extent to which untreated adults act as a reservoir for reinfection of treated children (Njenga *et al.*, 2011). This study therefore sought to determine the potential contribution of adult populations to the maintenance of schistosome and STH transmission in southern Zambia.

Methods

Study area and population

The catchment areas for the two districts were Magoye (16.0017S, 27.6041E) and Munjile (16.019 2S, 27.5010E) in Mazabuka, and Matuwa (16.4004S, 28.6843E), Nabutezi (16.4339S, 28.5433E) and Manchamwva (16.4670S, 28.4004E) in Siavonga. Geographically, Siavonga District is very mountainous and spreads out along the north bank of Lake Kariba in the Zambezi Valley. The valley is very hot in the summer months from October to March but is cooled by the summer rains from November to April. Fishing is a major activity for local villagers (Chimbari *et al.*, 2003). Mazabuka District lies 120 km south of the capital Lusaka and the terrain is generally flat with numerous small rivers. The majority of the population in Magoye and Munjile are subsistence farmers involved in the household and in cash crop production. In both the Siavonga and Mazabuka study sites formal education levels are low, rarely going beyond 7th grade (11–13 years old). Access to sanitation facilities and clean water is low in all the study sites, and schistosome and STH infections are common. Currently, control programmes in Zambia against schistosomiasis and STH are targeting children aged less than five years and school-aged children using the Mass Drug Administration (MDA) approach. There are currently no MDA initiatives against schistosomiasis and STH in adults. However, the first countrywide MDA against lymphatic filariasis was done in 2015, but there was still the challenge of low treatment coverage in some areas, which left some adults untreated and therefore still with the potential to contribute to transmission of the infections. There is also the problem of lack of the drugs praziquantel, mebendazole and albendazole for routine use in health facilities in Zambia. Praziquantel, in particular, is unavailable in most health centres most of the time.

Study design and sampling

This cross-sectional study was conducted in April and May 2013, and was part of a baseline survey for a larger study focusing on the cost-effectiveness of community-directed treatment of schistosomiasis and STHs in school-age and under-five children. Villages in each of the five study sites (the catchment areas of each health facility included in the study) were grouped into local geographical areas (LGAs) based on the existing neighbourhood health committee zones. Five LGAs were created in each site. The stratified sampling method, using LGA as stratum, was used to select the households from which participants would be sampled. A total of 125 households in Siavonga and 250 households in Mazabuka were selected from each LGA. That is, 500 households were selected from each of the three sites in Siavonga District, and 750 households from each of the two sites in Mazabuka District. The sampling frame for all eligible adults, both female and male, was created by conducting a census. The systematic random sampling method was then used to select the 3000 study participants, from which stool and urine samples were collected.

Sample collection and examination

Parasitological data were collected using the standard Kato-Katz technique and urine filtration method. The stool and urine samples were collected between noon and 4 pm. For stool samples, a duplicate 41.7 mg Kato-Katz cellophane thick smear of a single stool sample was examined from each participant. Each participant was given a plastic container in which to put the sample. Samples were collected from the participants by field assistants the following day and examined within 60 minutes of preparation of slides for hookworm eggs and later that day or the next day for other STH eggs (Mugono *et al.*, 2014). Egg counts were expressed as eggs per gram of stool (EPG).

The urine filtration method was used to process urine samples, which were collected in wide-mouth plastic containers. Immediately the urine was collected, 10 ml were aliquoted using disposable syringes and filtered through 12 μm polycarbonate membrane filters. Only one urine sample was collected for the diagnosis of *S. haematobium*. Infection intensities of *S. haematobium* were expressed as number of eggs counted per 10 ml urine. Quality control was ensured by re-examining a randomly selected 5% of sample of all slides by the principal investigator. No significant discrepancies in readings of slides were observed.

Data handling and analysis

Microsoft Excel spreadsheets were used for data entry. All statistical analysis was performed using STATA 13 (StataCorp, College Station, TX, USA). Proportions were computed to report prevalence and heavy infection intensities. Crude egg counts were recorded and converted to EPG for *S. mansoni* and STH infections and eggs per 10 ml of urine for *S. haematobium.* As described by Njenga *et al*. (2011), infected individuals were categorized as having light or heavy infection intensity based on the WHO classifications (WHO, 2006). For *S. mansoni* infections, light infections were 1–399 EPG and heavy intensity infections were ≥400 EPG. For *S. haematobium*, light-intensity infections were 1–49 eggs/10 ml of urine and heavy-intensity infections ≥50 eggs/10 ml of urine. Hookworm infections were classified as light intensity when egg counts were 1–1999 EPG, and heavy intensity when counts were ≥2000 EPG. *Ascaris lumbricoides* infections were classified as low-intensity infections when egg counts were 1–4999 EPG and heavy-intensity infections when counts were ≥5000 EPG. The analysis on infection intensity was done only on infected individuals.

Ethical considerations

The research proposal was reviewed and approved by the ERES CONVERGE ethics review committee in Zambia (ref.: 2013-jan-001). In addition, the Ministry of Community Development, Mother and Child Health reviewed and approved the protocol. During the study, written informed consent was sought from each participant after an explanation of the objectives and data collection methods of the study. Confidentiality and anonymity were ensured. Participants found positive were followed up and treated.

Results

Characteristics of study population

Table 1 summarizes the distribution of the included adults by study site, age group and sex. A total of 2829 individuals were sampled in the two districts: 1385 (49.0%) from the Siavonga sites and 1444 (51.0%) from the Mazabuka sites. The proportion of females was significantly higher than that of males ($p < 0.001$). Of the sampled adults, 66.1% were aged between 18 and 49 years, and 33.9% were older than 49 years. The median age for the whole sample was 39 years.

Table 1. Characteristics of the study population, Zambia, 2013

	n (%)	*p*-value[a]
Study site		
Magoye (Mazabuka District)	697 (24.6)	
Munjile (Mazabuka District)	688 (24.3)	
Matuwa (Siavonga District)	476 (16.8)	
Nabutezi (Siavonga District)	475 (16.8)	
Manchamvwa (Siavonga District)	493 (17.4)	
Total population	2829	
Sex		
Male	1276 (45.1)	
Female	1553 (54.9)	<0.001
Age group		
18–49	1871 (66.1)	
>49	958 (33.9)	<0.001

[a]Pearson's χ^2.

Prevalence of S. mansoni *and* S. haematobium

Table 2 summarizes the results for the prevalence of schistosome and STH infections. The overall prevalence of *S. mansoni* was 2.9% (95%CI 2.3–3.5), with the highest prevalence (7.0%; 95%CI 4.7–9.3) being recorded at the Nabutezi site. The district-aggregate prevalence for *S. mansoni* was significantly higher in Siavonga District (5.7%; 95%CI 4.5–6.9) compared with Mazabuka District (0.0%) ($p < 0.001$). The overall prevalence of *S. haematobium* for all sites was 6.8% (95%CI 5.9–7.7), with the highest prevalence (12.4%; 95%CI 9.4–15.4) being recorded in the Nabutezi site. The district-aggregated prevalence of *S. haematobium* was significantly higher in Siavonga District (8.2%; 95%CI 6.8–9.6) compared with Mazabuka District (5.3%; 95%CI 4.1–6.5) ($p < 0.001$). The overall prevalence of any schistosome infection for all sites was 9.7% (95%CI 8.6–10.8), with Siavonga District sites having a significantly higher prevalence (13.9%; 95%CI 11.3–16.5) compared with the Mazabuka District sites (5.3%; 95%CI 4.2–6.5) ($p < 0.001$).

Prevalence of STH

The overall prevalence of *A. lumbricoides* for all sites was 4.6% (95%CI 3.8–5.4), with the highest prevalence (9.9%; 95% CI 7.3–12.5) being recorded in the Manchamvwa site. The district-aggregated prevalence of *A. lumbricoides* was significantly higher in the Siavonga sites (9.3%; 95%CI 7.8–10.8) compared with the Mazabuka sites (5.8%; 95%Cl 4.6–7.0) ($p < 0.001$). The overall prevalence for hookworm for all sites was 3.6% (95% CI 2.9–4.3). The highest hookworm prevalence was 5.1% (95%CI 3.1–7.1), recorded at the Matuwa site. The district-aggregate prevalence of hookworm did not differ significantly between the Siavonga (3.9%; 95%CI 2.9–4.9) and Mazabuka District sites (3.2%; 95%CI 2.3–4.1) ($p = 0.37$). The overall prevalence of any STH in all sites was 9.8% (95%CI 8.7–10.9), with Siavonga District sites having a significantly higher prevalence (12.1%; 95%CI 10.4–13.8) compared with the Mazabuka District sites (7.4%; 95%CI 6.0–8.8) ($p < 0.05$).

Table 2. Prevalence of *S. haematobium, S. mansoni* and STH infections in adults, by study site, Zambia, 2013

			Prevalence (*n* (%))					
District	LGA[a]	*n*	*S. mansoni*	*S. haematobium*	Any schistosome	*A. lumbricoides*	Hookworm	Any STH
Mazabuka	Magoye	697	0 (0.0)	48 (7.0)	48 (6.9)	43 (6.2)	15 (2.2)	57 (8.2)
	Munjile	688	0 (0.0)	26 (3.8)	26 (3.8)	38 (5.5)	30 (4.4)	46 (6.7)
Siavonga	Matuwa	476	23 (4.8)	6 (1.3)	29 (6.1)	42 (8.8)	24 (5.0)	58 (12.2)
	Nabutezi	475	33 (7.0)	59 (12.4)	92 (19.4)	44 (9.3)	18 (3.8)	56 (11.8)
	Machamvwa	493	26 (5.3)	54 (11.0)	80 (16.2)	49 (9.9)	14 (2.8)	61 (12.4)
All areas		2829	82 (2.9)	193 (6.8)	275 (9.7)	216 (7.6)	101 (3.6)	278 (9.8)

[a]LGA = Local Geographical Area, a grouping of neighbouring villages within a defined geographical location.

Infection intensities for S. mansoni, S. haematobium *and STH*

The intensities of *S. mansoni, S. haematobium, A. lumbricoides* and hookworm infections in the five study sites are summarized in Tables 3 and 4. The majority were light-intensity infections. Overall, 6.1% (95%CI: 0.90–11.3) and 9.3% (95%CI 5.2–13.4) of individuals infected had a high-intensity infection of *S. mansoni* and *S. haematobium*, respectively. It is worth noting that there were no adults with high-intensity infections of *S. mansoni* in the two Mazabuka District study sites (Magoye and Munjile). The highest proportions of infection with *S. mansoni* and *S. haematobium* were both in the Matuwa site: 8.7%, (95%CI 2.8–20.2) and 16.7% (95%CI 13.1–46.5), respectively.

Overall, 4.6% (95%CI 1.8–7.4) of adults infected with *A. lumbricoides* had high-intensity infections, with the highest proportion being in the Nabutezi site (9.1%; 95%CI 0.6–17.6). For hookworm infections, 20.8% (95%CI 12.9–28.7) of adults in all five sites had high-intensity infections, with the highest proportions being observed in the Magoye (33.3%; 95%CI 9.5–57.2) and Matuwa sites (33.3%; 95%CI: 14.5–52.2).

Table 3. Infection intensity of *S. mansoni* and *S. haematobium* in adults by study site, Zambia, 2013

		Study site					
Parasite	Infection rate	Magoye	Munjile	Matuwa	Nabutezi	Manchamvwa	All sites
S. mansoni	Number positive	0	0	23	33	26	82
	Median EPG	0	0	18	24	13	11
	Heavy infection (%)	0 (0.0)	0 (0.0)	2 (8.7)	2 (6.1)	1 (3.8)	5 (6.1)
S. haematobium	Number positive	48	26	6	59	54	193
	Median eggs per 10 ml	31	20	18	13	27	22
	Heavy infection (%)	1 (2.1)	2 (7.7)	1 (16.7)	8 (13.6)	6 (11.1)	18 (9.3)

S. mansoni: light intensity = 1–399 EPG; heavy intensity = ≥400 EPG.
S. haematobium: light intensity = 1–49 eggs per 10 ml; heavy intensity = ≥50 eggs/10 ml.

Table 4. Infection intensity of *A. lumbricoides* and hookworm in adults by study site, Zambia, 2013

		Study site					
Parasite	Infection rate	Magoye	Munjile	Matuwa	Nabutezi	Manchamvwa	All sites
A. lumbricoides	Number positive	43	38	42	44	49	216
	Mean EPG	182	136	231	421	103	214
	Heavy infection (%)	2 (4.7)	1 (2.6)	1 (2.4)	4 (9.1)	2 (4.1)	10 (4.6)
Hookworm	Number positive	15	30	24	18	14	101
	Mean EPG	241	124	308	222	219	223
	Heavy infection (%)	5 (33.3)	3 (10.0)	8 (33.3)	3 (16.7)	2 (14.3)	21 (20.8)

A. lumbricoides: light intensity = 1–4999 EPG; heavy intensity = ≥5000 EPG.
Hookworm: light intensity = 1–1999 EPG; heavy intensity = ≥2000 EPG.

Discussion

Studies to quantify the extent of schistosome and STH infections in populations have traditionally focused on school-age children living in endemic areas as the majority of public health interventions targeting STH and schistosome infections use school-based deworming, which has been shown previously to provide benefits to untreated groups within populations (Miguel & Kremer, 2004). Recently, studies have begun to focus on infections in adult populations, recommending a change in treatment strategy to include other population groups, in addition to school-age children (Njenga *et al.*, 2011; Abou-Zeid *et al.*, 2012). The current study has demonstrated a relatively high prevalence of *S. haematobium* and *A. lumbricoides* infections in the adult population of Mazabuka and Siavonga Districts, Zambia. The WHO guidelines recommend regular preventive chemotherapy with anthelminthic drugs as a public health intervention to control these infections and reduce morbidity (WHO, 2006). The results of this study, however, suggest that if adults are left untreated in areas where the prevalence of helminthic infections is high in this group, the adults may perpetuate transmission of infections and may act as a source of reinfections of school-age children, and thus reverse or reduce the gains achieved by deworming the children. This is particularly a potential risk for populations where there are no MDA initiatives in adult populations using praziquantel against schistosomiasis, mebendazole against STH and albendazole against STH or lymphatic filariasis, or where there is low treatment coverage. Treatment for lymphatic filariasis with albendazole, however, is likely to impact STH infection rates.

Past studies conducted in Zambia have shown that schistosome and STH infections are widespread and endemic in most parts of the country, though with varying prevalence (Bhagwandeen, 1976; Mutengo *et al.*, 2009; Halwindi *et al.*, 2011; Shawa *et al.*, 2014). Although all age groups get infected, these diseases disproportionately affect the poor, especially children, and culminate in serious chronic disease conditions (Salam *et al.*, 2014). For instance, records at the University Teaching Hospital in Lusaka, Zambia, dating as far back as 1976, show that over 141 cases of urinary schistosomiasis in adults resulted in carcinoma of the bladder – the third most important malignancy seen in the Zambian population. Furthermore, between 2001 and 2007, Mutengo *et al.* (2009) reviewed records of 38 patients, mostly adult females, with prominent cases of genital schistosomiasis, a condition with egg granuloma inflammation causing prostatitis and infertility in men and in female genitalia leading to cervical and vaginal ulcers, ectopic pregnancies and miscarriages in women, as well as infertility and suspected increased risk of HIV infection. Most of these cases were not suspected and only detected accidentally during the course of other examinations or from post-mortems and histopathology studies (Mutengo *et al.*, 2009).

Njenga *et al.* (2011) reported 41.7% prevalence of hookworm and 18.2% prevalence of *S. haematobium* infection among adults living in the rural villages of Kwala District, costal Kenya. Poole *et al.* (2014) in Malawi, using soluble egg antigen ELISA, reported 94.5% prevalence of *S. haematobium* in mothers in Chikhwawa District whose general awareness of the disease was very low. Yet, they daily bathed or washed with their children in open waters, a behaviour likely to sustain high transmissions within that community. In southern Kordofan State in Sudan, Abou-Zeid *et al.* (2012) demonstrated an overall 6.9% prevalence of urogenital schistosomiasis in an adult population with variations according to geographical location. Mothers were also found to have the highest prevalence, with illiteracy being highly associated with the disease. According to Ekundayo *et al.* (2007) in Nigeria, a strong correlation exists between parental socioeconomic status and intestinal parasitosis in children; hence infections were highest in children whose parents are unemployed or petty traders. Chimbari *et al.* (2003), in southern Zambia, found a higher incidence of urogenital and intestinal schistosomiasis among the adult fishing population of Siavonga than in school-aged children.

The findings of this study support previous observations on infection levels in adult populations. It is likely that the adult populations of Mazabuka and Siavonga Districts suffer from chronic pathology, and potentially transmit infection in southern Zambia. Although the majority of these infections were categorized as light intensity, 5–10% of *S. mansoni* and *S. haematobium* infections could be characterized as heavy infections, and heavy infections with hookworm were found in more than 20% of infected adults. According to Ekundayo *et al.* (2007), individuals that are heavily infected in such communities ought to be identified and treated, preferably in the dry season when transmission conditions are least favourable. Otherwise, widespread dispersal of ova and larvae is expected to continue and children are in danger of perpetual infection and reinfection throughout their lives.

Some of the factors that propagate the transmission of schistosoma infections in Siavonga include the local population's regular fishing activities, washing and vegetable watering, school-aged children wading and bathing and tourists' swimming and boating activities. Chimbari *et al.* (2003) suggested an overall reduction in schistosoma infection prevalence over the years: 35.5% in 1994, 19.4% in 2001 and the current 8.2% for *S. haematobium*, and 60.1% in 1994, 33.5% in 2001 and 5.7% for *S. mansoni*. It is worth noting that in the catchment area of Nabutezi alone, the prevalence was higher for both *S. haematobium* (12.4%) and for *S. mansoni* (7.0%) than the aggregated district prevalence, indicating that predisposing factors differ from place to place. Chimbari *et al.* (2003) attributed the high prevalence in Siavonga to a combination of deficient toilet facilities and easy access to the snail-infested Lake Kariba. The lack of basic social amenities also affects the adult population in Mazabuka, who are highly susceptible to faecal-contaminated soils, as witnessed by the 33.3% of the hookworm positives who had heavy infection intensity. In consonance with Ekundayo *et al.* (2007), hookworm infections were persistent in the subsistence farming adult population. This indicates that the sampled adult population, and especially pregnant women, also have the potential risk of having iron-deficiency anaemia due to intestinal blood loss (Njenga *et al.*, 2011). The current study did not detect any infection caused by *T. trichiura* in adults.

Continued yearly treatment of school-aged children and under-fives alone has the potential to drastically moderate the worm burden in Zambia and elsewhere (Halwindi *et al.*, 2011; Mwandawiro *et al.*, 2013; Shawa *et al.*, 2014; Salam *et al.*, 2014). However, this study's findings, and those of Njenga *et al.* (2011) and Abou-Zeid *et al.* (2012), suggest that infected adults have the potential to be a reservoir of continued transmission and thereby a cause of reinfection among treated children under current control programmes, and thus present an impediment to these. Furthermore, the findings agree with the suggestion of Njenga *et al.* (2011) that the inclusion of adults in control programmes might have the prospective of significantly improving the efficacy and effectiveness of current control strategies. With the low levels of formal education in the two sampled adult populations of Mazabuka and Siavonga, which depend on subsistence farming and fishing for their livelihoods, drug administration alone may not be effective. Rather, it is imperative to couple chemotherapy with improvements in sanitation and health education that mainly focus on promoting healthy behaviour in order to disrupt the transmission cycle of schistosomes and STHs (Halwindi *et al.*, 2011; Salam *et al.*, 2014).

Although the current mass drug administration against urogenital and intestinal helminths primarily targets children, who are certainly the most vulnerable, this study's findings show that adult populations harbour infections and could contribute to disease transmission in their respective communities. There is a need to consider alternative treatment strategies that include adults, and the necessity to improve in water and sanitary facilities should not be ignored.

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