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Schistosoma mansoni Infection along the Coast of Lake Victoria in Mwanza Region, Tanzania

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Abstract. Prevalence and intensity of *Schistosoma mansoni* infection according to age, sex, and occupation were investigated in 100 first-year students (aged 7–8 years), 100 schoolchildren (aged 9–12 years), and 50 adults (aged 20–55 years) from 149 villages. The schoolchildren provided three stool specimens while the rest provided only one specimen. A total of 31,865 individuals provided at least one specimen with an overall prevalence of 38.5% and geometric mean intensity of positives of 107.0 eggs per gram of feces. With the exception of first-year students, males had higher prevalence than females ($P < 0.0005$). Schoolchildren had higher prevalence than first-year students that again had higher prevalence than adults. There was no sex difference in intensities among the children, but adult males had higher intensities than adult females. Intensity among the children was higher than that of the adults ($P < 0.0005$). Prevalence was significantly higher in those having fishing as their main occupation. Three stools samples were obtained from 13,119 schoolchildren, resulting in a prevalence of 38.1% if only one sample was included, 47.5% including two samples, and 52.6% if all three samples were included.

INTRODUCTION

Schistosomiasis is caused by blood-fluke parasites of the genus *Schistosoma* and is one of the poverty-related neglected tropical diseases. Since 1985, when a World Health Organization (WHO) Expert Committee recommended that schistosomiasis control program should adopt morbidity control with chemotherapy as the main strategy,[1] there has been an increased focus on praziquantel administered to selected populations.[2] Despite this, many areas in sub-Saharan Africa do still have high prevalences and intensities of schistosomiasis especially among school-age children. The most recent conservative estimate of the number of people infected worldwide is more than 230 million.[2] The United Republic of Tanzania is the country with the second highest number of cases in the region (19 million) only surpassed by Nigeria.[3] Both intestinal and urogenital schistosomiases are highly endemic in the country and cause significant morbidity.[4] Intestinal schistosomiasis, caused by *Schistosoma mansoni*, is particularly abundant in communities living along the shores of Lake Victoria.[4] Thus, in Mwanza Region of Tanzania, it was possible in 2011 to select 150 schools out of 300 schools screened, where schoolchildren had a *S. mansoni* prevalence of 25% or more with just a single stool sample (double Kato-Katz smears; site selection survey).

The site selection survey was undertaken to find study sites for the Schistosomiasis Consortium for Operational Research and Evaluation (SCORE) project in Tanzania. The site selection survey screened 50 schoolchildren between the age of 13 and 14 years from each school. Those found positives were treated with praziquantel (40 mg/kg body weight).

SCORE is a multi-country study with an overall goal to provide an evidence base for program decisions about mass drug administration (MDA) to control *S. mansoni* and *S. haematobium* in countries with different prevalence levels. In the Tanzanian study, the aim was to determine the strategy for MDA that provides the greatest reductions in prevalence and intensity of *S. mansoni* in school-aged children after 4 years of intervention in an area of prevalence of 25% or more.

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This article describes the baseline results of the above study and reports age, sex, occupation, and prevalence and intensity of *S. mansoni* in the investigated individuals. For the part of the population (children aged 9–12 years), where three stool samples were obtained, prevalence and intensities were compared in relation to number of samples.

MATERIALS AND METHODS

Ethics statement on subject recruitment. The study was reviewed and approved by the Medical Research Coordination Committee (MRCC) of the National Institute for Medical Research (NIMR), Tanzania (ethics clearance certificate no. NIMR/HQ/R.8a/Vol.IX/1022) and the University of Georgia Institutional Review Boards, Athens, GA (2011-10353-1). Only children who assented to participate and had parental or guardian consent were eligible for inclusion.

Before requesting stool samples, the reason for the survey and the procedure of sample collection were explained to the children and the adult population in the communities including local leaders, school administration, teachers, and health and education personnel. Each included person was assigned an identification number and results were entered in a confidential file. Included communities were treated according to the SCORE protocol with a standard oral dose of praziquantel (40 mg/kg body weight) using a standardized dose pole.[5] The trial was registered with ClinicalTrials.gov (NCT02162875).

Study area and population. This cross-sectional study was carried out from August to November 2011 in schools and communities within a 10 km distance from Lake Victoria in Mwanza Region of Tanzania where a prior site selection survey (see above) had identified a prevalence of *S. mansoni* of 25% or more. Mwanza Region lies in the Lake Victoria basin and has many water bodies including small and larger rivers, swamps, and ponds ideal for snail habitats. The transmission of *S. mansoni* in the area is perennial. The elevation of Mwanza region is between 1,000 and 1,500 meters above sea level, with humidity from 50% to 65% and with average midday temperatures between 26°C and 32°C. The coolest months are from June to October and the warmest months from December to March. There are two rainy seasons. The long rains fall from mid-March to May, with rains virtually every day, while the

short rains fall during November, December, and sometimes in January. The average annual rainfall is 1,122 mm. The predominant ethnic group is the Wasukuma. Subsistence farming (animal husbandry and crops) and fishing in Lake Victoria are the main income-generating activities in the area. The region had a total population of 2,772,509 according to the 2012 National Population and Housing Census,[6] 3 regional hospitals, 9 district hospitals, 46 health centers, and 363 dispensaries. There are at least two Community Health Workers in each village. The region has 1,139 primary schools enrolling a total of 902,367 schoolchildren, which is more than 95% of all school-age children in the region.

A total of 150 villages were selected for the study and in each village 100 first-year students (aged 7–8 years) and 100 schoolchildren between the age of 9 and 12 years from one school in each village and 50 adults (aged 20–55 years) from each community were randomly selected and included in the study.

Parasitological investigation. Participants were given stool containers and asked to provide fresh stool specimens. The 100 schoolchildren (9–12 years of age) provided stool specimens on 3 consecutive days, while the 100 first-year students and 50 adults only provided one specimen. One exception to this was in eight villages selected for morbidity assessments (to be reported elsewhere) where first-year students and adults also provided three specimens.

A temporary field laboratory was set up in each of the visited schools and duplicate Kato-Katz thick smears using a 41.7 mg template[7] were processed from each specimen on the spot. The slides were transported to the National Institute for Medical Research in Mwanza and examined for *S. mansoni* eggs. Infections with soil-transmitted helminths were not investigated as *Ascaris lumbricoides* and *Trichuris trichiura* have been recorded to be seldom present[8,9] and because eggs of hookworms were not visible because of the time span between preparation and reading.

Number of eggs on each slide were multiplied by 24 and expressed as eggs per gram of stool (epg) and the mean from the total number of slides per person was calculated. The egg counts were found to be over dispersed and were thus natural log transformed, and intensities were reported as geometric mean (GM) intensity of epg among positive individuals only.

Statistics and data analysis. Because three stool samples were collected from most of the children aged 9–12 years and only one stool sample from a majority of the other age groups, comparisons between sexes, age groups, occupations, and villages were done on only one stool sample to make comparisons meaningful. Data were analyzed using IBM statistics SPSS version 20 (IBM, Armonk, NY). χ^2 tests were used for testing differences in proportions, while one-way analysis of variance (ANOVA) was used to assess differences in intensities of infection. All tests and confidence intervals used the 5% level of significance.

RESULTS

***S. mansoni* distribution by village.** A total of 149 schools/villages were included as it was necessary to exclude one school/village because of its low cooperation. Village prevalence (including all age groups) based on one stool sample ranged from 2.9% to 94.5% with 61.7% (92/149) of villages having prevalence above 25% and 32.2% (48/149) having prevalence above 50%. Thus, almost 40% of the included villages had prevalence below the targeted 25% (see Discussion). GM intensity of positives in the same villages ranged from 18.0 to 456.4 epg with 36.2% (54/149) of villages having GM intensity above 100 epg.

Prevalence of *S. mansoni* by age and sex. A total of 31,865 individuals were included from 149 schools/villages, and provided at least one stool specimen. The age groups were from 7 to 55 years of age, 15,352 (48.2%) were males and 16,513 (51.8%) females. A majority (26,940; 84.5%) were school-going

TABLE 1

Age- and sex-related prevalence and intensity of *Schistosoma mansoni* infection from one stool sample in 31,865 randomly selected children and adults along the coast of Lake Victoria in Mwanza region, Tanzania

		Schistosoma mansoni		
Age groups (years)	*N*	Positives	Positives in % (95% CI)*	Intensity (epg) of positives GM (95% CI)†
Males				
7–8	5,938	2,259	38.0 (36.8–39.2)	113.2 (106.5–120.4)
9–12	6,852	3,077	44.9 (43.7–46.1)	115.8 (110.0–121.8)
20–39	1,128	434	38.5 (35.8–41.2)	72.1 (63.5–81.8)
40–55	1,434	406	28.3 (25.9–30.7)	70.0 (61.9–79.1)
Total	15,352	6,176	40.2 (39.4–41.0)	107.5 (103.6–111.4)
Females				
7–8	6,420	2,393	37.3 (36.1–38.5)	114.5 (107.9–121.4)
9–12	7,730	3,191	41.3 (40.1–42.5)	113.9 (108.4–119.6)
20–39	1,313	321	24.4 (22.0–26.8)	53.5 (46.7–61.4)
40–55	1,050	195	18.6 (16.2–21.0)	45.4 (38.7–53.4)
Total	16,513	6,100	36.9 (36.1–37.7)	106.5 (102.7–110.4)
Both sexes				
7–8	12,358	4,652	37.6 (36.8–38.4)	113.9 (109.1–118.8)
9–12	14,582	6,268	43.0 (42.2–43.8)	114.8 (110.8–118.9)
20–39	2,441	755	30.9 (29.1–32.7)	63.5 (57.8–69.7)
40–55	2,484	601	24.2 (22.4–26.0)	60.8 (55.1–67.2)
Total	31,865	12,276	38.5 (37.9–39.1)	107.0 (104.3–109.7)

CI = confidence interval; epg = eggs per gram; GM = geometric mean.

*Prevalence was similar between sexes in the 7–8 years group ($P = 0.38$), while males in the other three age groups had higher prevalence than females ($P < 0.0005$). For sexes combined, there were significant differences in prevalence by age group ($P < 0.0005$) with the following sequence: 9–12 > 7–8 > 20–39 > 40–55 years (χ^2).

†There was no sex difference among the schoolchildren (age group 7–8 and 9–12 years), but for adults (20–39 and 40–55 years), males had higher intensities than females ($P = 0.002$ and $P < 0.0005$, respectively). For sexes combined, there were no difference between the two groups of children and between the two adult groups, but intensity of the children was significantly higher ($P < 0.0005$) than that of the adults (one-way ANOVA).

TABLE 2

Intensity levels according to the WHO guidelines of *Schistosoma mansoni* infection in 12,276 children and adults from one stool sample along the coast of Lake Victoria in Mwanza region, Tanzania

Intensity levels of *S. mansoni*	Infected	Infected in % of total (95% CI)
Light (1–99 epg)	6,227	50.7 (49.8–51.6)
Moderate (100–399 epg)	3,550	28.9 (28.1–29.7)
Heavy (≥ 400 epg)	2,499	20.4 (19.7–21.1)
Total infected	12,276	100

CI = confidence interval; epg = eggs per gram; GM = geometric mean; WHO = World Health Organization.

children in the age group 7–12 years. The age- and sex-related prevalence and intensity based on one stool sample are presented in Table 1.

Prevalence was similar between sexes in the 7–8 years group, while males in the other three age groups had higher prevalence than females ($P < 0.0005$). For sexes combined, the different age groups had significantly different prevalence ($P < 0.0005$) with the following sequence: 9–12 > 7–8 > 20–39 > 40–55 years.

As regards intensities, there were no sex difference among the schoolchildren (age group 7–8 and 9–12 years), but for adults (20–39 and 40–55 years), males had higher intensities than females ($P = 0.002$ and $P < 0.0005$, respectively). For sexes combined, there were no difference between the two groups of children and between the two adult groups, but intensity in children was significantly higher ($P < 0.0005$) than that of the adults. The overall prevalence and GM intensity of positives was 38.5% and 107.0 epg, respectively.

***S. mansoni* intensity levels.** According to WHO guidelines, the intensity levels are divided into light (1–99 epg), moderate (100–399 epg), and heavy (≥ 400 epg).[1] Almost half of the investigated individuals (49.3%) had moderate to heavy infections, and 20.4% had heavy infections (Table 2). In this particular infection group, 874 individuals (35.0%) had egg counts of 1,000 epg or more. A total of 840 (96.1%) of these very heavy infected individuals were found in the age group of 7–12 years.

***S. mansoni* infection and occupation.** The prevalence and intensity related to main occupation among the adult population based on one stool sample is shown in Table 3. A total of 4,618 (93.8%) stated that farming was their main occupation. Prevalence of *S. mansoni* was significantly higher in those having fishing as their main occupation, while teachers had significantly lower prevalence. There were no significant differences between the intensities among the adult occupational groups. The group "other" is excluded from any comparisons.

***S. mansoni* prevalence and multiple samples.** It was possible to collect one stool sample on 3 consecutive days from 13,119 schoolchildren (9–12 years of age). The prevalence related to the number of fecal samples among these children is shown in Table 4. For any of the three stool samples, the mean prevalence was 38.1%, which increased to 47.5% if any of two stool samples were included. If all three stool samples were included, the prevalence increased to 52.6%. In contrast to the increasing prevalence with increasing stool samples, the intensities decreased with increasing number of samples (108.5, 78.0, and 65.1 epg, respectively).

DISCUSSION

The prevalence of *S. mansoni* infection was high along the Lake Victoria shoreline in Mwanza Region of Tanzania. Thus, one-third of the villages had prevalence of 50% or more based on just one stool sample and approximately the same one-third of the villages can be categorized as being moderately to heavily infected. Several villages had lower than the targeted 25% prevalence, which was due to the fact that the study population in this study included first-year students and adults who probably had a lower prevalence of infection compared with the 13- to 14-year-old schoolchildren who were included in the site selection survey. The 13- to 14-year-old children were not included in this baseline study, so treatment of the positives at the site selection survey was not expected to influence the baseline results.

Comparisons with previous studies need to consider age of study population and difference in the investigated number of stool samples and the diagnostic test used to evaluate whether *S. mansoni* prevalence and intensity of infections have changed over time. As few studies have investigated the same age groups and used the same diagnostic test and diagnostic efforts as in this study, there are not many ideal studies to compare with. Therefore, a comparison has been made to the few previous studies reported from the area. In 1997, schoolchildren from both inland and coastal schools were investigated in Magu district. The study found an overall prevalence of 10.9% from only one stool sample using the formal-ether technique, but all schools close to the lake had a prevalence of 25% or more. Intensities were not investigated.[8] In 2001, adults in one village in each of the districts Ukerewe and Ilemela were investigated using one stool sample and the Kato-Katz technique. Prevalence of *S. mansoni* in the two villages was 78% and 38%, respectively, while the GM intensities were 156 and 47 epg,

TABLE 3

Prevalence and intensity of *Schistosoma mansoni* infection from one stool sample related to main occupation in 4,925 randomly selected adults in the age group 20–55 years and in the school-going children along the coast of Lake Victoria in Mwanza region, Tanzania

Main occupation	*N*	*S. mansoni* positives	*S. mansoni* positives in % (95% CI)*	*S. mansoni* intensity (epg) of positives GM (95% CI)†
Business	148	31	20.9 (14.2–27.6)	65.1 (44.1–96.1)
Fishing	38	17	44.7 (28.6–60.8)	77.3 (38.5–155.2)
Farmer	4,618	1,297	28.1 (26.7–29.5)	62.3 (58.1–66.9)
Teacher	98	6	6.1 (2.3–12.9)	61.0 (17.2–215.8)
Other	23	5	21.7 (4.5–38.9)	19.7 (8.9–43.5)
Total adults	4,925	1,356	27.5 (26.3–28.7)	62.3 (58.2–66.7)
School-going children	26,940	10,920	40.5 (39.9–41.1)	114.4 (111.3–117.6)
Total	31,865	12,276	38.5 (37.9–39.1)	107.0 (104.3–109.7)

CI = confidence interval; epg = eggs per gram; GM = geometric mean.
*Fishing > farmer ($P = 0.023$); farmer > business ($P = 0.057$); business > teacher ($P = 0.001$) (χ^2).
†No difference in intensities among the different adult occupational groups (one-way ANOVA).

TABLE 4

Prevalence and intensity of *Schistosoma mansoni* infection in relation to stool samples investigated among 13,119 schoolchildren (9–12 years of age), where 3 stool samples were obtained along the coast of Lake Victoria in Mwanza region, Tanzania

Number of stool samples investigated	*S. mansoni* positives	*S. mansoni* positives in % (95% CI)	*S. mansoni* intensity (epg) of positives, GM (95% CI)
One (two smears)			
Sample 1	5,181	39.5 (38.7–40.3)	105.3 (101.3–109.4)
Sample 2	5,004	38.1 (37.3–38.9)	107.9 (103.8–112.2)
Sample 3	4,811	36.7 (35.9–37.5)	112.2 (107.8–116.8)
Mean		38.1	108.5
Two (four smears)			
Samples 1 and 2	6,363	48.5 (47.7–49.3)	76.2 (73.3–79.2)
Samples 1 and 3	6,319	48.2 (47.4–49.0)	77.5 (74.6–80.5)
Samples 2 and 3	6,028	45.9 (45.1–46.7)	80.2 (77.2–83.4)
Mean		47.5	78.0
Three (six smears)			
Samples 1, 2, and 3	6,897	52.6	65.1

CI = confidence interval; epg = eggs per gram; GM = geometric mean.

respectively.[10] The most recent study was performed in 2006 in Magu district investigating school and preschool children. The prevalence and GM intensity of *S. mansoni* based on the Kato-Katz technique on two stool samples were 39.7% and 50.7 epg, respectively.[9] Although the study from 2001 seems to have higher prevalence than this study, the most comparable study is the study from 2006, which have slightly lower prevalence and intensity. Thus, the prevalence and intensity in the area seems not to have decreased at least during the last 8 years.

Prevalence was significantly higher in males than in females in all age groups apart from the first-year students (age group of 7–8 years), where boys and girls had similar prevalence. One possible explanation for this observation could be that the difference in risk behavior that often explains the difference in infection prevalence between sexes was not fully developed in these first-year students. It is possible that boys and girls of that age do still have similar water contact behavior.

The age-prevalence association is as expected with prevalence peaking in the 9–12 years age group and decreasing gradually with host age.[2] The first-year students had significantly lower prevalence than the 9–12 years students, which indicates that this age group either has less risky behavior compared with their older peers, or the infection have not yet reached its maximum.

In children, there was no sex difference in intensities, while adult males have higher intensities than females. The difference among the adults is not surprising as a high proportion of males in these communities are expected to fish in the lake either as their main occupation or in addition to being farmers. It is, however, surprising that so few states fishing as their main occupation (see below). Children had higher intensities of *S. mansoni* infection than adults, which reflect a lower acquisition of worms in adulthood. This lower acquisition is probably a combination of reduced exposure to infection and age-dependent changes in innate resistance or acquired immunity.[11] It is worrying that half of the investigated individuals had moderate to heavy *S. mansoni* infections and that one fifth (20.4%) had heavy infections. It is also of concern that we found 840 children in the age group 9–12 years of age with egg counts of 1,000 epg or more.

As mentioned above, it is surprising that only 38 adults stated that fishing was their main occupation, while 93.8% stated that they were farmers. It reflects unfortunately that the used questionnaire was not optimal and that questions should have been asked to the respondents about secondary and even third occupation. On the other hand, the results do show some expected differences. Those who stated that they fish had higher prevalence than those who farm, which again had higher prevalence than those doing business. Teachers were the group with the lowest infection.

The huge sample size gives an opportunity to make valid comparisons on the effect of multiple stool samples on prevalence and intensities. Thus, increasing the diagnostic effort from two to four Kato smears increased the prevalence from 38.1% to 47.5%. A further increase to six smears increased the prevalence from 47.5% to 52.6%. In a study in Côte d'Ivoire, two, four, and six smears resulted in a prevalence of approximately 50%, 70%, and 80%, respectively, with a percentage increase between the levels of 40% and 14%,[12] which is higher than the figures in this study where the percentage increase was 24.7% and 10.7%, respectively. In a meta-analysis on the effects of sampling and diagnostic effort on the assessment of schistosomiasis, the difference in prevalence between two and four Kato smears were only 10%, which is lower than in this study.[13]

Intensity decreased with number of stool samples (108.5 to 78.0 to 65.1 epg), which is not surprising as some positive children had zero egg counts in some of their samples and including these will lower the mean egg counts. In the abovementioned meta-analysis, increasing the number of Kato smear did not affect the mean fecal egg counts,[13] and the Côte d'Ivoire study showed a similar lack of effect (68 to 63 to 65 epg).[12] The only explanation for this difference must be that this study has a considerable higher number of children with a mixture of positive and negative smears compared with the study from Côte d'Ivoire and the studies in the meta-analysis. Obviously, the above results are dependent on the transmission level. When the transmission level decreases and the number of negative individuals or individuals with low intensities increases, the importance of improving the diagnostic effort becomes more pronounced.

In conclusion, individuals living on the shores of Lake Victoria in Mwanza Region have a high risk of being infected with *S. mansoni*, and the risk appears to have been unchanged over several years. This risk is especially high in school-age children. In this particular setting, it seems to make sense to increase the number of stool samples from one to two, while the third sample may not be worth the effort.

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