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ORIGINAL ARTICLE

Helminth prevalence among adults in rural Kenya: a stool survey for soil-transmitted helminths and schistosomiasis in Nyanza province

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Background: Soil-transmitted helminth (STH) prevalence in children is high in rural southwestern Kenya, but adult prevalence data are scarce. A 2010 study of a village in Nyanza province found a pediatric STH prevalence of 44% using a direct stool-smear method. Adult STH prevalence and associated predictors was measured in the same village.

Methods: Adults (≥18 years) presenting at the out-patient department of the small hospital or community outreach events completed a short questionnaire and provided stool samples. Light microscopy for ova and larvae was conducted using a stool concentration technique to improve sensitivity. Multivariable regression models were used to identify predictors of STH prevalence.

Results: Among 344 adults, STH prevalence was 15.7% (54/344). Hookworm was most common (13.1%; 45/344), followed by *Ascaris lumbricoides* (6.1%; 21/344) and *Trichuris trichiura* (0.6%; 2/344). Twelve participants (3.5%; 12/344) had multiple STHs and three (0.9%; 3/344) had *Schistosoma mansoni*. Female sex, older age and lower education level were significant STH predictors.

Conclusions: Adult STH prevalence was lower than previous studies of children from the same village. Adults with the identified risk factors had a prevalence of ≥20%, which may warrant periodic, targeted deworming of adults with these risk factors given the low cost and low toxicity of anthelmintic drugs.

Keywords: Adult, Kenya, Helminths, Infection, Prevalence, Schistosomiasis

Introduction

The WHO estimates that over one billion people globally are infected with soil-transmitted helminths (STH).[1] This leads to as many as 39 million disability-adjusted life-years (DALYs) lost and 135 000 directly-attributable deaths per year.[1] Pediatric STH prevalence is more often assessed than among adults, given higher parasite burden and more severe potential clinical consequences in children. A meta-analysis and spatial modeling of 945 prevalence studies in Kenyan children across several decades found an average STH combined prevalence (roundworm [*Ascaris lumbricoides*], hookworm [*Ancylostoma duodenale* or *Necator americanus*] and/or threadworm [*Trichuris trichiura*]) of 37% nationally and 42% in Nyanza, with prevalence estimates appearing lower in more recent years. It also concluded that approximately 2.8 million school-age children in Kenya live in areas where once- or twice-yearly mass deworming is warranted.[2] Two previous studies carried out in a rural community of about 16 500 persons in southwestern Kenya demonstrated a decline in pediatric STH prevalence from 68% in 2007 to a still-high 44% in 2010 (both direct stool-smear surveys). The authors speculated that the apparent decline was due to an introduction of a periodic mass deworming program in the schools in the interval between surveys, and perhaps also aided by a community initiative to increase access to clean water, sanitation and hygiene training.[3,4]

While water, sanitation and hygiene initiatives reduce STH burdens on entire populations,[5,6] interventions targeting adult infections are far less common than among children, which are typically anchored on periodic mass deworming.[7–9] Because data are scarce for rural Kenyan adults, the objective of this study was to determine the accompanying adult STH prevalence and identify socio-demographic factors associated with STH infection in the same rural community in southwestern Kenya where the pediatric surveys had been conducted.[3,4]

Materials and methods

Study participants were enrolled from June to July 2011 from the out-patient department of the 12-bed rural Lwala hospital or via community member recruitment through one of four schools within the hospital catchment area. Inclusion criteria were adult age (18 years or older) and willingness and ability to produce a stool sample. Persons with known chronic liver or intestinal diseases and pregnant or nursing women were excluded. Hospital participants were recruited using announcements in the waiting room describing the project and soliciting volunteers. Community participants were recruited using announcements about the project distributed to children at the participating schools who were asked to deliver the announcement to their parents and other family members. Interested adults were instructed to come to the participating school on a specific day.

After obtaining consent, a brief survey was administered to obtain demographic and clinical information. Participants then provided a stool sample using a wooden stick and collection cup. The surveys and samples were coded with a unique identification number that confidentially linked them for each individual. All participants were subsequently given a single 400 mg dose of albendazole for empiric deworming. Patient charts were annotated to prevent repeated participation in the study. A list of identification numbers linked to participant names was kept by the hospital director in a secure location in order to provide one 20 mg/kg dose of praziquantel to participants with *Schistosoma mansoni* detected in their stool.

Stool samples were preserved using 10% formalin solution (5 ml of formalin for every 1 cc of stool sample). After fixation of 1 cc of stool for at least 30 minutes, samples were processed with the Para-Pak SpinCon Stool Concentration System (Meridian Bioscience, Inc., Cincinnati, OH, USA) according to the manufacturer's instructions. The earlier generation of this concentration method (Para-Pak Macro-Con), has performed similarly to four other concentration techniques: Fecal Concentrator Kit (Remel, Lenexa, KS, USA), Fecal Parasite Concentrator (Evergreen Scientific, Los Angeles, CA, USA), Trend FeKal CON-Trate (Trend Scientific, Inc., St. Paul, MN, USA) and a standardized gauze filtration method.[10] Since stools were examined when they were fresh, the standard merthiolate-iodine formaldehyde stain was not required since both merthiolate and formaldehyde are preservatives. Rather, specimens stained with Dobell's iodine were visualized under 40 x magnification light microscopy. Based on detection of ova or larvae (*Strongyloides spp.* only), the presence or absence of the following parasites were documented: *A. lumbricoides*, hookworms (*A. duodenale* and/or *N. americanus*), *T. trichiura* and *Strongyloides stercoralis*. Although *S. mansoni* is not a STH, it was reported since its eggs could be visualized. Quantitative stool egg (or larvae) counts could not be performed due to limited field and laboratory expertise and resources.

Survey and stool sample data were entered into Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) and later imported into STATA/SE 12 (StataCorp, College Station, TX, USA). Prevalence data were reported for each STH and *S. mansoni* separately. Total STH prevalence was defined as infection with any of the STH (*A. lumbricoides*, *A. duodenale, N. americanus*, *T. trichiura and S. stercoralis*). Crude and adjusted prevalence ratios (PR) and 95% confidence intervals were calculated using log-linear regression models. Different sets of potential confounders were selected 'a priori' for each socio-demographic factor and its association with STH prevalence, resulting in separate multivariable regression models for obtaining the adjusted PR for each socio-demographic factor (details in Table 2 footnotes). Because two independent and self-selected populations participated in this study (school-based recruitment and hospital-based recruitment), interactions between study site and each of the socio-demographic risk factors being analyzed were assessed. All interaction p-values were >0.35 with the exception of education (p=0.09) and occupation (p=0.11). These two factors included categories with <5 STH-infected participants, making the lower p-values unstable and difficult to rely on. There is, therefore, no evidence of heterogeneity of the prevalence ratios between the two study populations and findings are reported for all participants combined. All prevalence ratios were further adjusted for study site to help control for unmeasured characteristics that might bias the associations between each risk factor and STH prevalence.

A sample size of 475 participants was estimated to be sufficient to detect a PR of at least 1.2 with 80% power, assuming 70% baseline STH prevalence and predictors with a frequency of at least 25% in each category. A high prevalence in adults similar to that found in an earlier survey among children was expected.[3] The desired sample size was not met due to the short time available to conduct the survey. Further, the observed prevalence was much lower than anticipated. 'Post hoc' power calculations indicate that only large prevalence ratios of at least 1.8 could be detected with 80% power, assuming 15% baseline STH prevalence and predictors present in at least 25% of the participants.

Results

In total, 373 adults were recruited into the study. Fifteen (4.0%; 15/373) participants from the school-based sample were excluded because of incomplete survey information and an additional 14 (3.8%; 14/373) participants were excluded because they lived outside the primary catchment area of the hospital (15 km radius around the hospital). The STH prevalence among the 29 excluded individuals was 10% (3/29) (two hookworm and one *A. lumbricoides*).

Of the 344 participants included in the final analysis, 51.5% (177/344) were recruited from the hospital and 48.5% (167/344) from the community. The prevalence of any STH was 15.7% (54/344). The majority of these infections were hookworm (13.1%; 45/344) or *A. lumbricoides* (6.1%; 21/344) and 3.5% (12/344) of participants were found to have infections with multiple species (Table 1). The STH prevalence among participants from school-based outreach was slightly higher (18.0%; 30/167), but not significantly different from the hospital-based participants (13.6%; 24/177; crude prevalence ratio [PR]=1.32; 95% CI 0.81–2.17). Hookworm prevalence among the school-based participants was also slightly higher, but not statistically significant (15.6% [26/267] vs 10.7% [19/177]; crude PR=1.45, 95% CI 0.83–2.52). Socio-demographic characteristics of the participants are reported in Table 2. The median age was 38 (interquartile range [IQR]=23), the median years of education was 7 (IQR=4), the median number of children living in the household was 2 (IQR=4), and the median distance from the hospital was 3 km (IQR=1). Adjusting for study site and age or sex, respectively, female sex (adjusted PR 2.11 [1.10, 4.04]) and age over 55 years (adjusted PR 2.03 [1.14, 3.62]) were associated with more than twice the prevalence of STH (Table 2). Completing some or all of secondary education (adjusted PR 0.25 [0.08, 0.80]) was

Table 1. Count and prevalence of soil transmitted helminths (STH) and *Schistosoma mansoni* among 344 adults in Nyanza province, Kenya

	School (n=167) %	Hospital (n=177) %	Total (n=344) %
Hookworm	26 (15.6)	19 (10.7)	45 (13.1)
Ascaris lumbricoides	10 (6.0)	11 (6.2)	21 (6.1)
Trichuris trichiura	1 (0.6)	1 (0.6)	2 (0.6)
Strongyloides stercoralis	0	0	0
Any STH	30 (18.0)	24 (13.6)	54 (15.7)
Multiple STH infections[a]	6 (3.6)	6 (3.4)	12 (3.5)
Schistosoma mansoni	1 (0.6)	2 (1.1)	3 (0.9)

STH: soil-transmitted helminths.
[a] Five with *A. lumbricoides* and hookworm, and one with *A. lumbricoides*, hookworm and *T. trichiura* in both the school and hospital (no gastrointestinal patients) samples.

associated with lower STH prevalence after adjustment for study site, age and sex. No associations were found for occupation, number of children living in the home, distance from the hospital or self-reported HIV status; while non-farming occupation was associated with a 50–70% lower STH prevalence. However, this estimate is unreliable given the wide confidence intervals.

Discussion

In adults in rural southwestern Kenya, a prevalence of 15.7% (54/344) for any STH infection was found using a sensitive stool concentration technique. This prevalence is lower than the pediatric survey data from the same area, as one would expect.[3,4] The overall prevalence (15.7%; 54/344) and specific prevalence levels for hookworm (13.1%; 45/344), *A. lumbricoides* (6.1%; 21/344) and *T. trichiura* (0.6%; 2/344) are much lower than those from a 2003 review that suggested that approximately 25 to 33% of adults in sub-Saharan Africa (SSA) were infected with STH.[11,12] More recent reports from large-scale studies suggest little change in overall prevalence of these helminthes.[13,14] Comparisons are difficult, however, due to variations in stool examination techniques,[15,16] geographical distribution of species[17] and age-specific susceptibility.[11,12] Crompton and Tulley found dramatic intra-country variability in a review of 10 countries in SSA with at least 10 published surveys reporting *A. lumbricoides* prevalence, suggesting large extant geographic variations in prevalence.[17] Hookworm infections in Africa may be more ubiquitous, while *A. lumbricoides* and *T. trichiura* may be more clustered and comparatively prevalent in urban environments.[12] Both *A. lumbricoides* and *T. trichiura* have a higher prevalence in children under 18 years of age, while hookworm infections have been reported to increase in prevalence with each decade of life.[11,12] This was seen in the study site, where *A. lumbricoides* was by far the most common infection in children aged 6–13 years (38% infected) from the 2010 pediatric survey,[4] while adults in this 2011 study had a much lower prevalence (6.1%; 21/344). Hookworm infections, alternatively, were more common in adults (13.1%; 45/344) than children (9%), with the caveat that the current technique likely underestimated the true STH burden. This diagnostic approach, however, was still more sensitive than the direct smear used in the earlier pediatric surveys.

Improved primary care, sanitation, hygiene, infrastructure and overall economic development has led to dramatic reductions in STH burden at a population level.[5] Unless treatment to reduce worm burden is a component of intervention campaigns aimed at reducing transmission (e.g., water and sanitation), there will be a long lag time between the intervention and measurable reductions in prevalence. Enteric helminths and schistosomes can live for many months, and some species for many years, within a given host.[18] Because of this, it is difficult to determine if the *S. mansoni* infections reported here represent locally-acquired infections. However, a recent study from Nyanza province demonstrated presence of *S. mansoni* infections among children living away from Lake Victoria,[19] indicating a more widespread distribution of this infection than previously thought. Ova from *A. lumbricoides* can remain viable in soil for months.[20] Over the past several years, clean water provision, hygiene education and increased latrine construction have all occurred at this study site, though the impact of these interventions cannot be quantified. Mass deworming has been used in the pediatric populations through school-based campaigns, though no mass projects targeting adult deworming have been carried out. Adult STH prevalence in this community was much lower than that of the children, likely due to better hygiene habits among adults, lower STH exposure, acquisition of partial immunity and, perhaps, to community hygiene initiatives.[21]

When considering potential socio-demographic factors associated with adult STH prevalence, age ≥55 years, less education and women were associated with increased prevalence, while non-farming occupations were associated with lower prevalence. Previous studies have shown that hookworm prevalence was highest among children and the elderly,[22–24] while education level has also been reported as an independent risk factor for STH infection.[25] The reason for these risk factors is unclear, however older age is likely correlated with decreased immunity to infection, as well as decreased adoption of newer hygiene and sanitation interventions. Similarly, lower education level may be correlated with decreased willingness or ability to engage in lifestyle changes that would reduce infection risk. A 2010 study of HIV-positive adults in Kenya identified a nearly two fold relative risk for infection among those without any education when compared to those having completed secondary school, and a negative correlation overall between increased education and prevalence of STH infection.[13] The finding that women have a higher prevalence compared to men was surprising given the lack of similar results in other surveys. It has been demonstrated that pregnant women are at increased risk of infection[26] and that women may have higher individual parasite burden compared to men,[14] but few studies have demonstrated a significant difference in STH prevalence between men and women.[14,22,24] One possible explanation for this finding in the current study is that women are more likely to be in direct contact with more heavily infected children, though this is likely the case in other study populations as well. This study showed moderately large associations for occupation and STH prevalence, but was not powered sufficiently to ensure that this was a valid finding. Nevertheless,

Table 2. Distribution of socio-demographic variables, soil-transmitted helminth (STH) prevalence, and adjusted prevalence ratios for an adult stool survey in Nyanza province, Kenya (n=344)

Variable	Total study sample n (%)	STH uninfected n (%)	STH infected n (%)	STH prevalence (%)	Crude PR (95% CI)	Adjusted PR (95% CI)
Study location						
School	167 (48.6)	137 (47.2)	30 (55.6)	18.0	1.32 (0.81–2.17)	NA
Hospital	177 (51.4)	153 (52.8)	24 (44.4)	13.6	Ref	
Sex						
Male	113 (32.9)	103 (35.5)	10 (18.5)	8.9	Ref	Ref
Female	231 (67.2)	187 (64.5)	44 (81.5)	19.1	2.15 (1.13–4.12)	2.11 (1.10–4.04)[c]
Age (y)						
18–35	159 (46.5)	138 (47.9)	21 (38.9)	13.2	Ref	Ref
36–55	122 (35.7)	106 (36.8)	16 (29.6)	13.1	0.99 (0.54–1.82)	0.98 (0.53–1.79)[d]
56+	61 (17.8)	44 (15.3)	17 (31.5)	27.9	2.11 (1.20–3.72)	2.03 (1.14–3.62)[d]
Education						
None	49 (14.3)	37 (12.8)	12 (22.2)	24.5	1.34 (0.76–2.37)	1.00 (0.52–1.90)[e]
Primary	214 (62.4)	175 (60.6)	39 (72.2)	18.2	Ref	Ref
Secondary[a]	80 (23.3)	77 (26.6)	3 (5.6)	3.8	0.21 (0.07–0.65)	0.25 (0.08–0.80)[e]
Occupation						
Farming only	237 (68.9)	190 (65.5)	47 (87.0)	19.8	Ref	Ref
Farming + non-farming	34 (9.9)	31 (10.7)	3 (5.6)	8.8	0.44 (0.15–1.35)	0.52 (0.17–1.57)[f]
Non-farming[b]	73 (21.2)	69 (23.8)	4 (7.4)	5.5	0.28 (0.10–0.74)	0.67 (0.22–2.06)[f]
Children at home						
None	97 (28.2)	75 (25.9)	22 (40.7)	22.7	1.75 (1.07–2.86)	1.29 (0.69–2.41)[f]
≥1 child	247 (71.8)	215 (74.1)	32 (59.3)	13.0	Ref	Ref
Distance to hospital						
<3 km	133 (38.7)	116 (40.0)	17 (31.5)	12.8	Ref	Ref
3–15 km	211 (61.3)	174 (60.0)	37 (68.5)	17.5	1.37 (0.81–2.33)	1.24 (0.71–2.18)[e]
Self-reported HIV status						
Negative	157 (45.6)	131 (45.2)	26 (48.2)	16.0	Ref	Ref
Positive	63 (18.3)	54 (18.6)	9 (16.7)	14.3	0.86 (0.43–1.74)	0.91 (0.43–1.89)[f]
Unknown	63 (18.3)	55 (19.0)	8 (14.8)	12.7	0.77 (0.37–1.60)	0.87 (0.41–1.82)[f]
Missing	61 (17.7)	50 (17.2)	11 (20.4)	18.0	1.09 (0.57–2.06)	1.10 (0.59–2.04)[f]

NA: not applicable; PR: prevalence ratios; ref: reference.
[a] Includes 20 with more than a high school education.
[b] Non-farming includes: teacher (23), student (15), business (11), tailor (6), two each of construction, clinic staff, community health worker, security and one each of crafts, engineer, HIV organization, home, house chores, mason, mechanic, nurse assistant, painter and piki driver.
[c] Adjusted for study location and age.
[d] Adjusted for study location and sex.
[e] Adjusted for study location, age and sex.
[f] Adjusted for study location, age, sex and education.

farming occupation is a highly plausible risk factor and has been reported elsewhere.[13]

While STH infections are typically cited for their detrimental effects on development in children,[12] serious health risks are experienced by adults as well,[7] notably anemia that is most marked with hookworm.[12,23] Other morbidity associated with STH infection include decreased cognitive ability, wage-earning capacity and birth weight of offspring.[23] Chronic helminth infections in adults may also be associated with malnutrition, linked to infection-related cytokine release and related anorexia and wasting.[23] There is some evidence that concomitant helminth infections in HIV-positive individuals may lead to higher viral loads, though this finding is not consistently supported throughout the literature.[27] The STH literature in adults is far less systematic and substantial in characterizing burden of disease, risk factors or benefits of targeted mass treatment than the data from children.

This study has its limitations. First, a more representative, population-based survey could not be done due to a lack of regional household mapping for generating randomly selected households and insufficient resources to conduct door-to-door surveys. Instead, a convenience sample of school- and hospital-based participants was recruited. It is possible that the STH prevalence and the associated risk factors are not representative of the entire population. However, the school-based prevalence and hospital-based prevalence were similar (18.0% [30/167] vs 13.6% [24/177]; p=0.26), and there was no evidence that the risk factor associations differed between the two populations. Given that each subgroup is recruited from a different source, the authors believe that the results may be generalizable to other community adults. Second, while it is helpful to have comparative data between adults and children from the same community, the studies were not contemporaneous and did not use the same stool diagnostic techniques.[3,4] While it would have been ideal to repeat a current prevalence evaluation among the pediatric population using the more sensitive technique, this was precluded by time and resource constraints. However, the most recent pediatric survey was conducted only 12 months prior to the current study. Third, each participant provided only one stool sample for testing, which may reduce sensitivity of detection in lightly infected persons, particularly for hookworm.[15,16] Fourth, a delay in processing stool samples can reduce sensitivity of detection for these worms, and a delay of only 3 hours from sample production to fixation can reduce sensitivity of hookworm detection by nearly 50%.[16] *A. lumbricoides* and *T. trichiura* detection rates are not affected nearly as much by the time delay due to their hardy eggshells. Ova in samples from participants recruited at the local schools may therefore have been under-reported as the samples were not fixed until returning to the clinic later in the afternoon. This may have led to slightly lower detection rates for hookworm among participants recruited at the schools, though the same day processing likely minimized this loss of ova integrity. Fifth, the density of worm burden in an individual is in fact a more useful proxy for disease burden than its prevalence,[28] but this study did not have the field or laboratory capacity to examine intensity. Given the lower-than-expected prevalence among adults in this study, it would have been particularly helpful to know the intensity to better understand the urgency of treating those infected. Sixth, information on recent anthelmintic treatment was not obtained. However, no adult mass dewormings had been carried out in the community, and the clinic infrequently prescribes anthelmintic therapy to adults.

Treatment for STH infection entails oral administration of a single dose of an affordable broad-spectrum anthelmintic drug such as mebendazole or albendazole (less often levamisole or pyranimide), as per WHO guidelines.[29] Given the high rates of reinfection in endemic areas, administration of anthelmintic drugs is recommended every 6 months for children and groups at increased risk, notably when prevalence rates exceed a 50% threshold.[29] All told, these infections affect nearly one in six adults in the study area, and treating those infected represents an important part of improving the overall health of the community. The generalizability of these results is unknown. While mass deworming in endemic communities even at lower prevalence rates may be cost-beneficial given the morbidity associated with infection and the low cost of anthelmintic chemotherapy, a more targeted approach may be preferable.[30] The community studied here was found to have a pediatric STH prevalence warranting biannual mass drug administration. Despite the pediatric infection rates and the higher prevalence associated with Nyanza province,[2] the adult prevalence of STH infection was not significant enough to conclusively warrant mass drug administration of any kind. This suggests that even in high-risk areas, infection among adults should not be assumed. In less endemic communities or among adult populations with low prevalence, identifying risk factors associated with higher prevalence, such as this study, could prove helpful in providing targeted anthelmintic chemotherapy and/or helping to inform additional or intensified sanitation and hygiene interventions to further reduce STH prevalence. Further studies should be conducted to identify the extent to which the risk factors identified for adult STH infection in this study are generalizable and therefore predictive in determining targeted treatment algorithms.

Conclusions

In this study, the point prevalence of STH infections (*A. lumbricoides*, *N. americanus*, *A. duodenale*, *T. trichiura* and *S. stercoralis*) among adults living in a rural Kenyan village was measured. Previously, the pediatric prevalence of the same infections had been measured at 44% using a direct smear technique in 2010. Using a more sensitive stool concentration technique, the adult prevalence was found to be 15.7% among the 344 adults surveyed. Significant risk factors for infection based on contemporaneous demographic surveys were age >55 and female sex, while completion of some or all secondary school was a significant protective factor. Because the STH prevalence was ≥20% in adults with at least one of identified risk factors, periodic, targeted deworming of adults with these risk factors may be warranted given the low costs and low toxicity of anthelmintic drugs.

Authors' contributions: JWA, AMK and SHV conceived the work; JWA implemented the laboratory specimen collection; MO assisted with study implementation and data collection; JWA and AMK performed analyses and wrote the initial draft of the manuscript; MO and SHV contributed revisions for the manuscript. All authors read and approved the final manuscript. AMK is the guarantor of the paper.

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Competing interests: None declared.

Ethical approval: Study procedures were reviewed and approved by the Institutional Review Board of Vanderbilt University and the executive director of the Lwala Community Hospital. Verbal consent was obtained from all participants prior to participation.

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