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<th>Spatial distribution and risk factors of Schistosoma haematobium and hookworm infections among schoolchildren in Kwale, Kenya</th>
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Title: Spatial distribution and risk factors of Schistosoma haematobium and hookworm infections among schoolchildren in Kwale, Kenya

Japanese title: 
ケニア国クワレ地区学童を対象としたビルハルツ住血吸虫及び鉤虫感染の空間分布とリスク要因


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Introduction:
Schistosomiasis and soil-transmitted helminthiasis (hookworm infections, ascariasis and trichuriasis) are among neglected tropical diseases targeted for control by the World Health Organization. In Kenya, approximately 17.4 million people are at risk of schistosomiasis and 9.1 million people are in danger of soil-transmitted helminthiasis. Large-scale schistosomiasis control programs are implemented in regions with diverse social and economic environments. A key epidemiological feature of schistosomiasis is its small-scale heterogeneity. Locally profiling disease dynamics including risk factors associated with its transmission is essential for designing appropriate control programs. This study, determined factors associated with the intensity of S. haematobium and hookworm infections among schoolchildren in Kwale, Kenya.

Materials and Methods:
A cross-sectional study of 368 children from six primary schools was conducted. Schistosoma mansoni and soil-transmitted helminths infections were examined by the Kato-Katz technique. For S. haematobium assessment, urine filtration method was utilized. Interviewer-administered questionnaires were used in gathering demographic/socioeconomic data from the study participant’s parents/guardians. Principal component analysis of wealth variables was conducted in SPSS. Children’s water contact and shoe wearing practices data were collected by administering a questionnaire to the children. Geographic coordinates for participants’ houses were captured with handheld global positioning units. Cluster analyses of infections was conducted in SaTScan software. Visualization of infection clusters was done in QGIS software. To identify factors associated with the intensity of S. haematobium and hookworm infections, we employed the glmmADMB library of the R statistical package to fit negative binomial generalized linear mixed models (NB-GLMM).
**Results:**

Trichuriasis and ascariasis were rare while *S. mansoni* was absent. For the intensity of *S. haematobium* infection, geometrical mean eggs in 10 ml urine was 3.1 (school range, 1.4–9.2). Hookworm geometric mean intensity was 3.2 eggs/g feces (school range, 0–17.4). Regarding the spatial distribution of *S. haematobium* and hookworm infections, heterogeneity was evident in Kwale. The intensity of *S. haematobium* infection was associated with religion and socioeconomic status (SES), while the intensity of hookworm infection was related to SES, sex, distance to river and history of anthelmintic treatment.

**Discussion:**

Identifying local risk factors for infection is important for informing target high-risk groups for control or generating data for designing alternative intervention strategies.

The proportion of children with the heavy intensity of *S. haematobium* infection was lower in Dumbule and Yapha compared to other schools in the study area. Focality of schistosomiasis even in small-scale geographical settings is a known phenomenon. Notably, the two schools with lower infection density were located in a dry area compared to the other schools. Such environments are not suitable for the survival of intermediate host snails of schistosomiasis. Since children attending a given school tended to cluster around the school, the school was included in the NB-GLMM model as a random factor to adjust for environmental effects. However, children from households affiliated to Islam excreted large numbers of *S. haematobium* eggs. To rule out school as a confounder we stratified the study population by the school. Nonetheless, the intensity of *S. haematobium* was consistently high among Muslims in all schools except Vyojato, where the infection intensity appeared to be similar both among Muslims and Christians. A previous study in Kwale reported Muslims had lower participation in control and related operational research for urogenital schistosomiasis and soil-transmitted helminthiasis by 50% compared to Christians. Health seeking behavior can be influenced by religious or cultural beliefs. The density of *S. haematobium* infection was high among children from households with low SES. Low SES correlates with poor sanitation and inaccessibility to safe water. All these can predispose individuals to a high risk of schistosomiasis.

Low hookworm infection levels in Amani, Dumbule and Yapha which are in a drier region can be explained regarding the survival rate of the infective larval stage. Its vitality depends on the presence of optimal soil humidity and temperature conditions. The risk of hookworm infection intensity declined with increased residence distance from the river. The three schools with low hookworm risk were in a drier area with a high mean distance of residence from the river. The higher intensity of hookworm infection was observed among children from poorer households. Poverty is associated with hookworm infection risks such as the absence of concrete floors in home dwellings, inadequate sanitation and lack of access to ant-helminths. History of anthelmintic treatment was marginally associated with the intensity of hookworm infection in Kwale. Individuals are prone to reinfection especially when chemoprophylaxis is the only strategy for hookworm control. Hookworm infection density was lower among children who received anthelmintic medication within one year before our study.

Limitations of our study are; we only inquired about river water contact not considering other sources of schistosomes. Second, we didn’t investigate *Schistosoma* larvae-infested water contact duration. Third, recall bias by interviewees, and finally, the study participants could easily confuse other medications taken in the past to be anthelminths.

The observed small-scale clustering of the *S. haematobium* and hookworm infections might imply less uniform strategies even at a finer scale for efficient utilization of limited resources.