

The potential of rapid screening methods for *Schistosoma mansoni* in western Kenya

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Data from 46 schools in western Kenya were used to investigate the performance of school-based questionnaires, on reported blood in stool and water-contact patterns, as indicators of the prevalence of human infection with *Schistosoma mansoni*. Prevalence of infection was associated with the prevalence of self-reported blood in stool, recent history of swimming and recent history of fishing. It was shown that use of a threshold of 30% of subjects reporting blood in stool would identify 42.9% of the 'high-prevalence' schools (i.e. prevalence $\geq 50\%$) and 87.5% of the 'low-prevalence' schools (i.e. prevalence $< 50\%$). A threshold of 25% reporting swimming would identify 57.1% and 93.7% of the high- and low-prevalence schools, respectively. Blood in stool appears to be too coarse an indicator to identify schools for mass treatment correctly. Although the use of multiple questions improved the diagnostic performance of the questionnaire in identifying the high-prevalence schools, it was unclear how questions can best be combined in other settings. However, there is a direct relationship between prevalence of *S. mansoni* infection and distance of the school from the lakeshore; analysis indicated that use of a threshold of 5 km from the lakeshore would correctly identify most (90%) of both the low- and high-prevalence schools. Distance to the lakeshore may therefore be used to screen schools in much of East Africa (i.e. those areas close to the Great Lakes where the infection is known to be prevalent and where much of the region's population is concentrated). In other areas of transmission, such as irrigation areas, further studies are still required.

For school-based health programmes, the World Health Organization recommends mass

treatment of children in schools where the prevalence of infection with *Schistosoma* spp. is $\geq 50\%$ (WHO, 1995). Several studies have demonstrated the usefulness of questionnaires about self-reported blood in urine to identify schools where there is such a high prevalence of *Schistosoma haematobium* infection (Anon.,

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1995). There is also evidence that self-reported blood in stool is correlated with *S. mansoni* infection at the school level (Hailu *et al.*, 1995; Booth *et al.*, 1998; Lengeler *et al.*, 2000; Utzinger *et al.*, 2000a). Despite these encouraging results, there remain uncertainties as to the usefulness of this approach for the large-scale screening of *S. mansoni* in Africa (WHO, 1999). Although blood in urine is a sensitive marker of *S. haematobium* infection, the reported signs and symptoms indicating *S. mansoni* infection generally show relatively low sensitivities and specificities (Gryseels, 1992). In particular, the signs and symptoms associated with *S. mansoni* infection, including blood in stool, bloody diarrhoea and abdominal pain, vary strongly between individuals and between communities from different endemic areas, with many of the signs and symptoms also being associated with other intestinal conditions (Gryseels, 1992). It may be that the questionnaire approach for *S. mansoni* could be improved by adding questions focusing on human-water contact (Barreto, 1993; Lima e Costa *et al.*, 1998; Utzinger *et al.*, 2000a, b) or that alternative screening methods need investigation (Booth *et al.*, 1998).

The aims of the present study, conducted in western Kenya, were to assess the performance of questionnaires asking children about self-reported health problems and water-contact patterns, and to investigate a more geographical approach for the identification of schools where mass treatment of *S. mansoni* infection is required.

SUBJECTS AND METHODS

Study Populations and Investigations

The present study formed part of an evaluation of a school-based deworming project, and was carried out in randomly selected schools beside Lake Victoria in the Budalangi and Funyula divisions of Busia district, Kenya. The results of preliminary research had demonstrated that *S. haematobium* was not present in the area. Paired questionnaire and parasitological data were collected for 25

schools in January–February 1998 (Brooker *et al.*, 2000) and for 21 other schools surveyed exactly 1 year later.

A questionnaire was administered to every child separately by a trained interviewer. This questionnaire asked children whether they had experienced any of a number of health problems in the previous 2 weeks, as well as the frequency and nature of their water-contact behaviours. The key questions included in the morbidity questionnaire were on blood in urine, blood in stool, bloody diarrhoea, abdominal pain, headache, cough, scabies, vomiting, earache, eye infection, malaria and schistosomiasis. The interview was conducted in an empty classroom and the answers recorded as ‘yes’, ‘no’ or ‘don’t know’.

In each school, the aim was to collect stool samples from 15 children in each of the classes 3–8 (seven randomly selected boys and eight randomly selected girls in one class and then eight girls and seven boys in the next, and so on) and then examine each sample, in duplicate, for the eggs of *S. mansoni* by the Kato–Katz thick-smear method. In many of the schools, however, fewer than 15 children were present in each of classes 6–8 and the overall sample size then fell below the target of 90 children/school. Because analysis of a single stool specimen/subject lacks sensitivity for individual diagnosis (Engels *et al.*, 1996) but can provide a reliable estimate of ‘true’ prevalence in the community (DeVlas and Gryseels, 1992), the focus in the present study was on community rather than individual diagnosis. The prevalences of blood in stool and of each main water-contact activity were calculated for each school and compared with infection prevalence as assessed by the presence of parasite eggs in faeces.

A hand-held global-positioning system (Magellan Systems, San Dimas, CA) was used to determine the geographical location of each school. The minimum distance between each school and Lake Victoria was calculated using version 3.2 of the ArcView software (ESRI Inc., Redlands, CA).

Data Analysis

The relationships between the prevalence of

TABLE 1
Parasitological and questionnaire results among 2913 schoolchildren in 46 schools in western Kenya

	Overall prevalence and (range in schools) (%)
INFECTION PREVALENCE	
Hookworm	75.1 (35.1–100)
<i>Ascaris lumbricoides</i>	42.8 (21.3–93.6)
<i>Trichuris trichiura</i>	51.4 (20.8–94.7)
<i>Schistosoma mansoni</i>	29.4 (0–100)
'QUESTIONNAIRE PREVALENCE' OF SELF-REPORTED:	
Blood in stool	21.5 (2.3–55.4)
Frequent water contacts	62.1 (26.7–92.6)
Swimming	19.8 (0–70.4)
Fishing	15.5 (0–63)

S. mansoni infection and each questionnaire variable, and between infection prevalence and the school's distance from the lakeshore, were assessed using Spearman's rank correlation analysis and logistic regression. In the regression models the number of water-contact variables was reduced so as to minimize the effects of correlations between these variables. The diagnostic performance of each of the questionnaire variables and of the distance from lakeshore for identifying the 'high-prevalence' schools (i.e. those with prevalence of infection $\geq 50\%$) was assessed by calculating sensitivities, specificities, and positive and negative predictive values (see Table 3).

RESULTS

Overall, 2913 children aged 8–20 years in 46 schools took part in the study: 1738 children were examined in 25 schools in 1998 and 1175 children in 21 schools in 1999. The prevalences of helminth infection, self-reported blood in stool, and main water-contact patterns (Table 1) did not differ significantly between the two groups of schools.

The results of correlation analysis (see Fig.) demonstrated significant associations between the prevalence of *S. mansoni* and the prevalences of a recent (self-reported) history of swimming ($r = 0.6$; $P > 0.001$), recent (self-re-

ported) history of fishing ($r = 0.42$; $P = 0.005$) and self-reported blood in stool ($r = 0.43$; $P = 0.003$). No significant association was observed between prevalence of *S. mansoni* and prevalence of (self-reported) frequent water-contact ($r = -0.16$; $P = 0.274$). However, the prevalence of *S. mansoni* infection was highest in schools directly on the lakeshore and decreased markedly with distance from the lake [$r = -0.68$; $P < 0.001$; Fig. (f)].

The significant relationships between *S. mansoni* infection and self-reported blood in stool or recent history of swimming could be explained by the significant correlation between both of these questionnaire variables and the distance from the lake ($r = -0.55$ and $P = 0.002$ for blood in stool, and $r = -0.58$ and $P < 0.001$ for swimming). However, the results of the logistic regression analyses indicated that both of these variables were independently associated with the prevalence of *S. mansoni* infection (Table 2).

The diagnostic performances of reported blood in stool, reported swimming, and distance between the school and the lake are shown in Table 3. In accordance with previous studies, blood in stool showed only moderate diagnostic performance. Reported swimming showed a stronger diagnostic performance, and distance from lake had the highest diagnostic performance of all the variables investigated. The performance of the

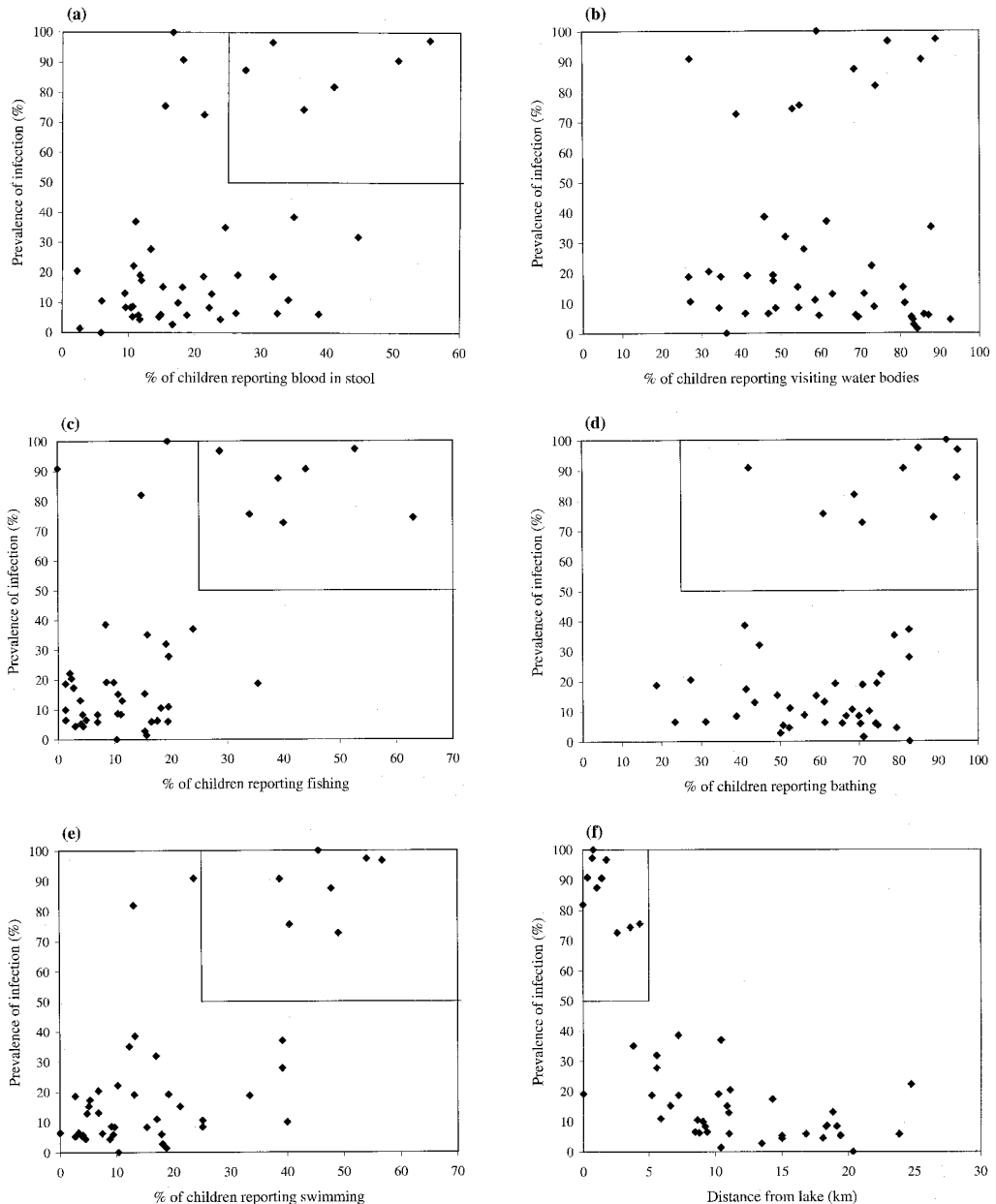


Fig. The relationships observed between the prevalence of *Schistosoma mansoni* infection in schoolchildren and those of blood in stool (a), visiting water bodies (b), fishing (c), bathing (d) and swimming (e) reported by the children, and between the prevalence of infection and the distance of the school investigated from Lake Victoria (f). Each point on each graph represents the result for one school. The rectangular box in a top corner of five of the graphs indicates those schools correctly predicted as having a high prevalence of *S. mansoni* infection (i.e. $\geq 50\%$) on the basis that the prevalence of the questionnaire variable is higher than the threshold set or the distance to the lake is < 5 km.

TABLE 2

Results of the logistic regression analyses on the relationship between the prevalence of *Schistosoma mansoni* infection in the schoolchildren and the questionnaire variables or the distance between the school and Lake Victoria

Variable*	B	S.E.	Residual deviance	P
Constant (null deviance)	-2.61	0.31	1545	
Reported swimming	0.06	0.003	706	< 0.0001
Reported blood in stool	0.04	0.004	514	< 0.0001
Distance from lake (km)	-0.08	0.01	468	< 0.0001

* Only the results for the significant variables are shown. The other variables investigated in the regression analysis were reported frequent water-contacts, reported fishing, reported bathing and others explored in the morbidity questionnaire, as well as the mean age and percentage male of the children investigated.

questionnaire was increased when questions on blood in stool and swimming were combined. For example, when a prevalence of self-reported blood in stool of > 25% was combined with a prevalence of a self-reported recent history of swimming of > 25%, the positive and negative predictive values became 83.3% and 87.5%, respectively. Adding closeness to the lake (i.e. distance < 5 km) to this combination resulted in still higher values, of 100% and 87.8%, respectively.

DISCUSSION

The present results provide further evidence that the prevalence of self-reported blood in stool is only a moderate predictor of schools with a high prevalence of *S. mansoni* infection (Lengeler *et al.*, 2000; Utzinger *et al.*, 2000a). However, they also indicate that the questionnaire approach for *S. mansoni* can be improved by adding questions on water-contact behaviour. The usefulness of such an approach has been demonstrated previously in Brazil, where a combination of several risk factors was shown to be correlated with *S. mansoni* infection (Barreto, 1993; Lima e Costa *et al.*, 1998). Similarly, the results of a study among Chinese schoolchildren demonstrated the potential of multiple risk factors to identify individuals infected with *S. japonica* (Zhou *et al.*, 1998). Working in Côte d'Ivoire, Utzinger *et al.* (2000b) found significant associations

between the prevalence of *S. mansoni* infection and each of three self-reported water-contact behaviours (fishing with nets, swimming/bathing, and crossing rivers) at the individual level among 322 schoolchildren, but no significant association with reported symptoms and/or reported diseases. Utzinger *et al.* (2000b) found that the diagnostic performance of these water-contact patterns was characterized by high specificities but low sensitivities and hence low negative predictive values. It is uncertain, however, how questions on water-contact patterns can be best combined at an operational level. It is difficult to generalize findings from one study because risk factors vary between places (Barreto, 1993; Lima e Costa *et al.*, 1998; Zhou *et al.*, 1998) and this may limit the potential of the approach. Further studies are clearly required in order to assess the potential of a combined questionnaire approach for *S. mansoni* in Africa.

In the present study population an important single risk factor appeared to be the distance between school and lake. This is a more easily assessed variable than any determined using questionnaires and provides a useful ecological proxy for risky water-contact behaviour; children living on or near the lakeshore are more likely to undertake risky water-contact behaviour than those who are distant from the lake. The children near the lake are also most likely to be exposed to intense transmission because of the differential

TABLE 3
 Diagnostic performances of questionnaire variables and of distance from lake

	Blood in stool, as assessed in:			Distance from lake (C)	Combination of variables:	
	Kenya (present study; A)	Côte d'Ivoire (Utzingler et al., 2000a)	Democratic Republic of Congo (Lengeler et al., 2000)		A and B	A, B and C
Threshold used	> 25%	> 22%	> 20%	< 5 km	> 25%	
No. of schools	46	60	57			
No. of children	2913	5047	5806			
PERFORMANCE INDICATOR						
Positive predictive value (%) [*]	42.9	73.2	44	100.0	57.1	83.3
Negative predictive value (%) [†]	87.5	78.9	87	91.7	93.8	87.5
Sensitivity (%) [‡]	60	88.2	62	100	80	50.0
Specificity (%) [§]	77.7	57.7	77	94.5	83.3	97.2

^{*} Percentage of schools predicted to have a high prevalence of *Schistosoma mansoni* infection (i.e. $\geq 50\%$) based on the defined threshold.

[†] Percentage of schools predicted to have a low prevalence of *Schistosoma mansoni* infection (i.e. $< 50\%$) based on the defined threshold.

[‡] Percentage of the high-prevalence schools (i.e. those with a prevalence of $\geq 50\%$) correctly predicted as such.

[§] Percentage of the low-prevalence schools (i.e. those with a prevalence of $< 50\%$) correctly predicted as such.

distribution of the snail intermediate hosts in relation to large water bodies (Nelson, 1958; McCullough, 1972; Kabatereine *et al.*, 1996; Lwambo *et al.*, 1999). The extent to which snail distributions differ between places might also explain why some of the present (Kenyan) schools that were > 5 km from the lakeshore had an infection prevalence of almost 40% whereas, in a previous study, in the Magu district of Tanzania (Lwambo *et al.*, 1999), schools that were > 5 km from the lakeshore all had prevalences of < 15%—even though the prevalence at 15 km from the lake was < 10% in both studies. These results indicate that the threshold distance used may need adapting for each region. Identifying the appropriate shore–school distance for use as a threshold in each setting is important, since extensive transmission of *S. mansoni* in East Africa occurs along the shores of the Great Lakes (Nelson, 1958; McCullough, 1972; Doumenge *et al.*, 1987). In Uganda, almost all transmission of this parasite takes place along lakeshores (Doumenge *et al.*, 1987). In Kenya and Tanzania, however (although high levels of transmission occur along the shores of Lake Victoria and Lake Tanganyika), transmission also occurs away from the main lakes. In Kenya, for example, *S. mansoni* is prevalent on the plateaux east of Nairobi (Sturrock *et al.*, 1996) and on the Kano Plain (Brown *et al.*, 1981). In Tanzania, new endemic localities have occurred as a result of increased irrigation, in Arusha (Foster, 1967; Fenwick, 1972) and in the south of the country (Sturrock, 1965; McCullough, 1972).

Further studies are required in these en-

demic areas away from the Great Lakes to investigate appropriate rapid screening methods for *S. mansoni* in these localities. A combination of questionnaire-derived variables may be appropriate. Nonetheless, distance from lake as an indicator of high prevalence has potential use among a large population exposed to *S. mansoni* transmission in East Africa, since the lake areas are among the most heavily populated areas in the region. For example, 29% of the estimated 102 million people in Burundi, Kenya, Rwanda, Tanzania and Uganda in 2000 lived in a district bordering a large water body (Deichmann, 1996; <http://www.census.gov>). On the basis of the present results, the control programme in Busia has recently adopted the 5-km shore–school threshold to identify high-risk schools throughout the entire district of Busia. Such an approach deserves wider investigation and implementation within the context of school-based control programmes in East Africa.

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