Predicting the community prevalence of schistosomiasis mansoni from the prevalence among 7- to 14-year-olds

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(*Received 7 October 1999; revised 7 February and 23 May 2000; accepted 3 June 2000*)

SUMMARY

The World Health Organization suggested that the prevalence of *Schistosoma mansoni* among 7- to 14-year-olds be used to guide treatment strategies in endemic areas. This study explores how well the prevalence in that age group predicted the overall prevalence in the community in data from stool examinations (Kato–Katz method) from 180000 people in 3 municipalities in Brazil in 1984 and 1985. The median prevalence was higher in 1984, before community treatment was introduced. There was a strong relationship between the prevalence among 7- to 14-year-olds and the overall prevalence in the community. We present sensitivities and positive predictive values for the use of prevalence in the indicator group to select communities for mass treatment as recommended by WHO. For a range of assumptions sensitivity and positive predictive value were never both above 80%. We suggest that the estimates of validity presented in this paper inform future evaluations of strategies for *S. mansoni* control.

Key words: schistosomiasis, *Schistosoma mansoni*, community treatment, validity, sensitivity, specificity.

INTRODUCTION

In order to increase the cost-effectiveness of the community-based treatment of *Schistosoma mansoni*, the WHO recommended in 1994 a strategy based on the prevalence of *S. mansoni* among indicator groups. They suggested that if the prevalence among 7- to 14-year-old school children is greater than 50%, the entire population should receive treatment; between 20 and 50% of all children aged 5–19 years should be treated; and less than 20%, only children with a positive test should be treated (WHO, 1994). The recommendation is not explicit about what level of prevalence in the entire community is expected when the prevalence in 7- to 14-year-olds is 50%.

How appropriate the WHO recommended strategy is depends on how well the prevalence in the indicator group relates to the overall prevalence. This can be established by analysing appropriate data. One such analysis was done for *S. haematobium* infection in Mali and found a high correlation ($r = 0{\cdot}90$) between the overall prevalence rate and that among 7- to 14-year-old children (Traore, Maude & Bradley, 1998). More recently Guyat, Brooker & Donnelly (1999) found similar results for *S. mansoni* infection in Africa, analysing data for 20000 stools in 6 countries. Unfortunately neither study estimated the validity of the use of prevalence in 7- to 14-year-old children to predict overall community prevalence, and thus did not evaluate the appropriateness of the WHO recommendation for treatment. We identified another source of useful data: the community surveys done by the Brazilian *S. mansoni* control programme in its early years. The programme began in 1975 in the northeast of the country and expanded in 1984 to the southeast region (Almeida Machado, 1982; Kano, 1992; Lima e Costa *et al*. 1996; Katz, 1998). It is a large and costly programme and during the first few years in some localities the whole community had stools examined (Kano, 1992; Lima e Costa *et al*. 1996).

This analysis aims to determine how well the prevalence of *S. mansoni* among 7- to 14-year-old school children predicted the overall prevalence in the community in Brazil, using this very large dataset collected during the routine *S. mansoni* control programme.

MATERIALS AND METHODS

Study area

In the State of Minas Gerais (Southeast Brazil), *S. mansoni* is endemic in 519 out of 852 municipalities (Lima e Costa *et al*. 1996). The analysis described in

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https://doi.org/10.1017/S0031182099006733 Published online by Cambridge University Press

this paper was performed on data from 3 municipalities (Brasilia de Minas, Coração de Jesus and Mirabela), situated in the São Francisco River Basin in Minas Gerais. These municipalities were used as sentinel municipalities for evaluating the impact of the programme and thus all age groups were tested during that period, whereas other municipalities restricted stool testing to children 7 to 14 years old. The activities of the Brazilian programme for schistosomiasis control began in these villages in 1984.

Schistosomiasis control programme

The activities of the control programme in the study area included (Almeida Machado, 1982) snail surveillance along all rivers and streams used by the population, and treatment with niclosamide every time infected and non-infected snails were found (Kano, 1992); complete censuses of each village for identification of participants (Lima e Costa *et al.* 1996); stool examination of all inhabitants by the Kato–Katz method (Katz, 1998), treatment with oxamniquine and person to person explanation of the disease cycle and prevention during an individual's treatment (WHO, 1994). The criteria for treatment varied with time. During the period relevant for this analysis (1984–86), in those villages where *S. mansoni* prevalence was less than 4%, only positive individuals (with *S. mansoni* eggs in their stools) were treated. When the prevalence was between 4 and 60% all inhabitants aged between 5 and 25 years were treated and when the prevalence was over 60% the entire community was treated. Further information on the programme is published elsewhere (Kano, 1992).

Survey methods

The data were obtained from field records containing the results of the censuses, stool examinations and treatments carried out in each village in 1984 (before introduction of the programme) and 1985 (after introduction of programme) by the National Health Foundation (Brazilian Ministry of Health, Montes Claros, Minas Gerais, Brazil). The prevalence of *S. mansoni* infection was calculated from these data.

Statistical methods

For each locality and year, the prevalence was calculated for both sexes combined in the age groups in which the data were collected: 0–6 years, 7–14 years, 15–25 years, 26–40 years, > 40 years.

In some localities very few children aged 7–14 – the indicator group for the present analysis – were examined. In many of these localities, the prevalence in this age group was either 0% (151 observations) or 100% (5 observations); a proportion of these were outliers in terms of the relationship between the overall prevalence and the prevalence in this age group. Because of this, all localities in which 10 or fewer children aged 7–14 examined were excluded from this analysis.

The remaining localities were grouped according to the prevalence of *S. mansoni* among 7- to 14-year-olds using the treatment strategy cut-off recommended by WHO: < 20%, 20–50% and ⩾ 50% (Katz, 1998). Within each subgroup, the sensitivity, specificity and predictive values were calculated using the prevalence in the whole community as the gold standard. For the levels of prevalence in 7- to 14-year-olds of < 20% and 20–50%, we used prevalence of < 20% and 20–50% in the entire community as the gold standard. The level of prevalence above 50% in the 7- to 14-year-olds (which triggers treatment of the entire community) is more critical, and for this we estimated a range of values of sensitivity, specificity and predictive values, using 3 different prevalences in the entire community as the gold standard: > 30%, > 40% and > 50%. This is because although the WHO recommendation is to treat the entire community when the prevalence in 7- to 14-year-olds is above 50%, the recommendation is not explicit about what is the presumed community prevalence in that situation. Sensitivity, specificity and predictive values were calculated with exact 95% binomial confidence intervals. As the indices are used to determine treatment of communities, we suggest that the most useful measures of validity are sensitivity and positive predictive value to high prevalences. In that context, sensitivity is a measure of what proportion of all communities with high prevalence are identified for treatment of the entire community and the positive predictive value is a measure of the number of communities that would receive treatment because they were classified as having a high prevalence when in fact they have a lower prevalence. We also present specificity and negative predictive values, to be used for consultation in particular cases of interest, for example for assessment of the usefulness of the index to monitor effectiveness of the programme. Correlations were assessed using Pearsons product moment correlation coefficient. All analyses were performed in Stata version 6·0 (Statacorp, 1999).

RESULTS

Data completeness and internal validity

Data were collected for 580 localities, each surveyed up to 2 times – in 1984 and 1985 – giving a total of 1154 observations of prevalence for a locality and year. Fifty of these 1154 observations (4%) were excluded from the analysis for 1 of 3 reasons:

https://doi.org/10.1017/S0031182099006733 Published online by Cambridge University Press

Table 1. Population and numbers examined by age group

(Figures are the mean over the 2 years of survey.)

Age (years)	Mean total population (% of all ages)	Mean total number examined (% of population)
0–6	18897 (21%)	17950 (95%)
7–14	20254 (23%)	19320 (95%)
15–25	19013 (21%)	16723 (88%)
26–40	14699 (17%)	13436 (91%)
> 40	16010 (18%)	14722 (92%)
Total	88872 (100%)	82151 (92%)

Table 2. Median prevalence (%) of *Schistosoma mansoni* by age group (interquartile range)

(Note: excluding communities in which 10 individuals or less were examined.)

Age (years)	1984 (399 communities)	1985 (405 communities)
0–6	5·9 (0–13·2)	0 (0–4·5)
7–14	20·0 (6·9–42·3)	4·9 (0–10·8)
15–25	30·8 (15·2–51·4)	9·6 (4·0–18·5)
26–40	27·3 (14·3–47·0)	14·3 (6·6–23·1)
> 40	18·2 (7·7–33·3)	9·1 (3·6–15·7)
All	21·0 (10·5–35·9)	8·1 (4·8–13·1)

missing data on the number examined for *S. mansoni*; missing data on the number positive for *S. mansoni*; or severe inconsistency such as the number of positive subjects exceeding the number examined, or the number examined exceeding the population of that locality. A further 299 observations were excluded because the indicator group consisted of less than or equal to 10 children. One further extreme outlier was excluded where the accuracy of the data was in doubt – a locality where 48 out of 48 subjects aged 7–14 were infected, but the overall prevalence was low. Thus the main results refer to 804 observations in 433 localities with complete data in either 1984 or 1985.

Prevalence of S. mansoni *infection*

The total number of people examined over the 2 periods was 164301. Table 1 presents the mean population (over the 2 survey periods) and numbers examined by age group. The numbers did not vary much between years (data not shown).

The median prevalence of *S. mansoni* in communities where more than 10 children were examined was 21·0% in 1984 and 8·1% in 1985. The prevalence was highest among those aged 15–25 years in 1984, and highest among those aged 26–40 in 1985 (Table 2).

Table 3. Sensitivity and specificity of the predictions (95% confidence intervals), separately for 1984 (before the start of the control program) and for 1985 (after the control program)

Prevalence among children aged 7–14	No. of communities/ total	For identifying communities with prevalence	No. of communities/ total	Sensitivity	Specificity	Positive predictive value	Negative predictive value
				1984			
< 20%	199/399	< 20%	192/399	93% (89–96)	90% (85–94)	90% (85–94)	94% (89–96)
20–50%	135/399	20–50%	170/399	70% (63–77)	93% (89–96)	88% (81–93)	81% (75–85)
⩾ 50%	65/399	⩾ 30%	134/399	48% (39–57)	100% (98–100)	98% (92–100)	79% (74–83)
		⩾ 40%	77/399	70% (59–80)	97% (94–98)	83% (72–91)	93% (90–96)
		⩾ 50%	37/399	89% (75–97)	91% (88–94)	51% (38–63)	99% (97–100)
				1985			
< 20%	364/405	< 20%	379/405	95% (93–97)	88% (70–98)	99% (98–100)	56% (40–72)
20–50%	39/405	20–50%	25/405	84% (64–95)	95% (93–97)	54% (37–70)	99% (97–100)
⩾ 50%	2/405	⩾ 30%	4/405	50% (7–93)	100% (99–100)	100% (16–100)	100% (98–100)
		⩾ 40%	1/405	100% (2–100)	100% (99–100)	50% (1–99)	100% (99–100)

https://doi.org/10.1017/S0031182099006733 Published online by Cambridge University Press

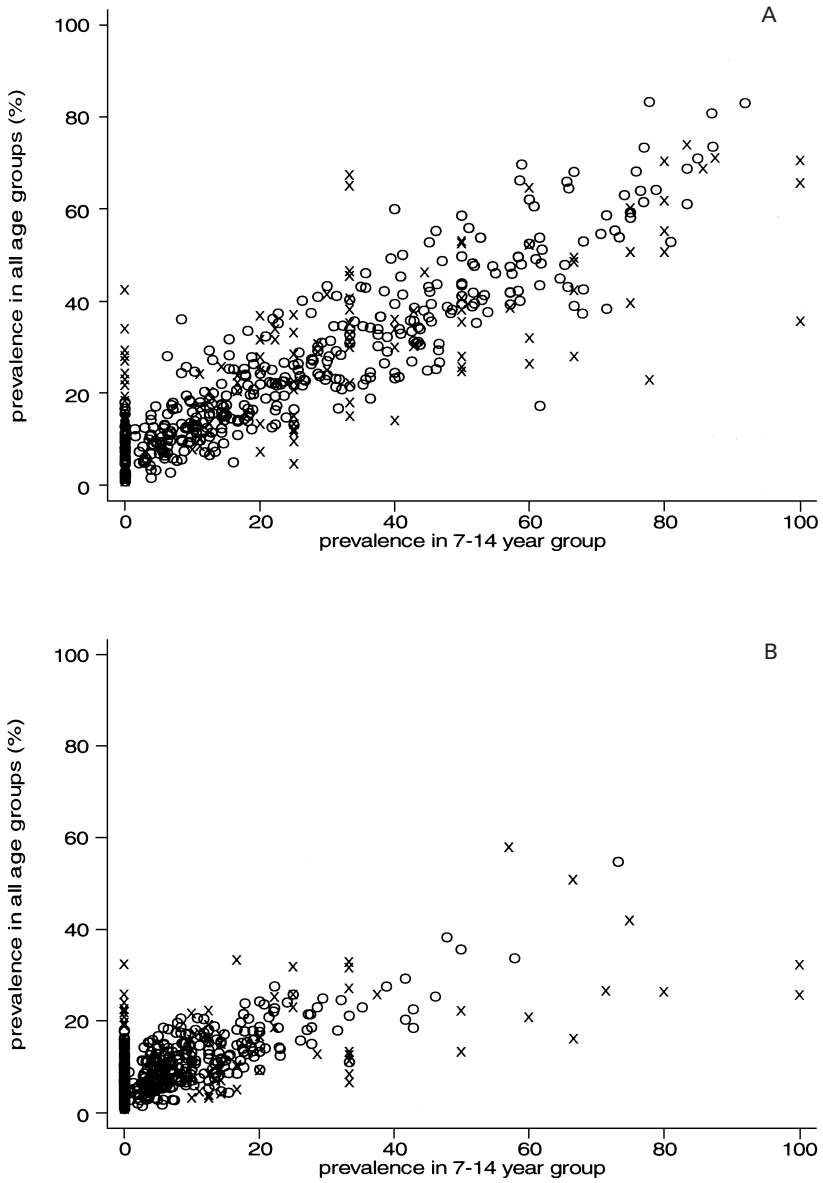

Fig. 1. Prevalence in all age groups against prevalence among those aged 7–14 years. (A) Before community control programme (1984). (X) Localities where 10 or fewer children aged 7–14 were examined. (O) Other communities. (B) After community control programme (1985). (X) Localities where 10 or fewer children aged 7–14 were examined. (O) Other communities.

Validity

The correlation between the prevalence of *S. mansoni* among 7- to 14-year-olds and the overall prevalence in 1984 was 0·918 ($P < 0{\cdot}001$) with communities with fewer than 10 subjects excluded. The same correlation for 1985 was 0·770 ($P < 0{\cdot}001$).

The sensitivity, specificity and positive and negative predictive values are shown in Table 3. It is immediately apparent that, repeating the pattern found for the correlation, the measures presented in Table 3 vary from one period to the other. The sensitivity for identifying low prevalence communities (< 20 % prevalence) was high and accurately estimated (93 %, 95 %CI 89–96). However, the sensitivity for identifying mid-prevalence communities was only 70 % (95 %CI 63–77) indicating that 30 % of communities in this prevalence range would be assigned treatment targeted at low or high prevalence communities. Both measures improved slightly in 1985 after the control programme, following the downward shift in prevalence at all ages. Of particular interest is sensitivity for identifying communities with high prevalence (based on a prevalence in the index group above 50 %). Before the control programme, this is 48 % of those with prevalence above 30 %, 70 % of those above 40 % and 89 % of those above 50 %. After the control programme was introduced, no communities had 50 % prevalence and only one had prevalence over 40 %. So although there were 2 communities where the prevalence in the indicator group was above 50 %, the validity measures are uninterpretable due to wide confidence intervals.

https://doi.org/10.1017/S0031182099006733 Published online by Cambridge University Press

The second measure of interest is the positive predictive value. Most of the communities identified as being in the low and mid-prevalence ranges were correctly identified, with PPVs in 1984 of 90% (95%CI 85–94) and 88% (95%CI 81–93) respectively. However, in the high prevalence range, positive predictive value before the control programme was 51% (if 50% prevalence in the entire community is presumed at the cut off point for treatment of the entire community), suggesting that about half the communities identified as high prevalence on the basis of the prevalence in the index group are wrongly classified. If the presumed trigger prevalences in the entire community are 40% and 30%, then the PPV increases to 83% and 98%.

After the control programme, the PPV was good for low prevalence communities, but fell to 54% in mid-prevalence communities, although inaccurately estimated (95%CI 37–70), and number were too small to interpret this measure in high prevalence communities.

DISCUSSION

This is the first study to present quantitative evidence of the validity of using the prevalence in 7- to 14-year-olds to predict the overall prevalence of *S. mansoni* in a community. We have shown that, in this population, the prevalence of *S. mansoni* among children aged between 7 and 14 years can detect communities with high prevalence (high sensitivity) well, but at a cost, since a proportion of those thus identified have lower prevalences. This balance changes with the presumed level of prevalence in the entire community at the cut off for the recommendation for treatment of the entire community, and according to whether there has been previous community treatment.

Before we discuss the implications of the findings for policy, let us consider how reliable these data are. The data were collected by the Brazilian Ministry of Health as part of the ongoing control programme and were not aimed specifically at validating the relationship between prevalence in the indicator group and prevalence in the whole population; this may explain the few inconsistencies in the data. Only 1 stool examination was made per subject, which decreases the validity of the measure (Jordan & Webbe, 1981). In spite of these limitations, the survey had extremely good coverage and has resulted in a large and reasonably complete data set. These data are as good as those likely to be available for screening communities for treatment, and the validity estimated is likely to apply well to routine data. Another limitation of the data is that age was grouped as 7–14 years, thus not allowing comparison to the age group 5–19 which WHO recommends should receive treatment if prevalence in 7- to 14-year-olds is between 20 and 50% (WHO, 1994).

The first point to note on the results is that the correlation between prevalence in the indicator age group and in the community changed before and after the control programme was implemented. It is well known that the shape of the age specific prevalence rate of *S. mansoni* infection changes after community treatment (Katz, Rocha & Pereira, 1980; Sleigh *et al*. 1986; Lima e Costa *et al*. 1993; Engels *et al*. 1994; Farag *et al*. 1993). This is to be expected since, in the presence of community treatment, the prevalence in each age group reflects (in addition to spontaneous recovery and treatment failure) the age-specific incidence of infection. In contrast, the prevalence in each age group before community treatment is a reflection of the duration of infection and the cumulative incidence, itself a function of incidence and age: the cumulative history of infection throughout their lives. Intensity of infection also tends to be heavier before mass treatment is introduced, particularly among adults, leading to a better performance of stool tests at the level of the individual. Thus, after the introduction of community treatment the age distribution of prevalence and, consequently, the relationship between the overall prevalence and that in any given age group must alter.

Our results show that in communities never previously treated the sensitivity of this indicator (prevalence 50% or higher in 7- to 14-year-olds) for estimating an overall prevalence equal to or higher than 50% is relatively high (but would still leave 11% of communities with prevalence above 50% not identified); there were not enough communities with high prevalence after treatment to estimate sensitivity accurately. Sensitivity was also very good in the lower and middle prevalence ranges, both before and after introduction of treatment. Thus, summarizing the validity of the WHO recommendation in terms of identifying communities that need treatment, the indicator appears to be quite adequate.

Does the use of the indicator lead to treatment of entire communities with low prevalence because it wrongly identifies them as having a high prevalence? The positive predictive value for prevalence over 50% was only 51% (95%CI 38–63) before introduction of the control programme. In other words, if the presumed prevalence in the entire community behind the trigger of mass treatment was 50%, and if the WHO recommendations had been followed in these communities, half of the treated communities would have been treated based on a wrong estimate of their prevalence. For other presumed levels of prevalence, the predictive value increased, but sensitivity decreased.

The intensity of infection tends to be heavier before the introduction of community treatment than afterwards and thus one would not expect, as observed, the sensitivity and specificity to perform better after the implementation of a control pro-

gramme (Katz *et al*. 1980; Sleigh *et al*. 1986; Farag *et al*. 1993; WHO, 1985).

Finally, the discussion – in Brazil and elsewhere – will continue on whether there may be better approaches to control, perhaps with less emphasis on repeated community treatment, and more investment in effective health education and implementation of adequate sanitation. This is a discussion that must be conducted on a scientific basis, well grounded on robust data. We suggest that other data sets are analysed to provide additional estimates of sensitivity, specificity and predictive value of the prevalence of *S. mansoni* in children aged 7–14 as an indicator of overall prevalence. We hope the findings presented here, and future findings are used to calibrate recommendations and to inform assessment of cost efficacy of different control strategies.

Dr Elizabeth Uchoa and Joselia AO Firmo kindly helped during the fieldwork. Without the support of Dr Carlos Catão Prates Loiola, from the Brazilian Ministry of Health in Brasilia, this work would not have been possible. L.C.R. is funded by the Higher Education Council, UK; R.S. was funded by the Department of Environment, and the Medical Research Council UK. M.F.F.L.C. and H.L.G. are funded by the National Research Council (CNPq) in Brazil. This study was sponsored by the Brazilian Ministry of Health/UNDP World Bank and by the Supporting Agency of Studies and Projects (FINEP), Brazil.

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