Available online at www.sciencedirect.com
ScienceDirect
International Journal for Parasitology 38 (2008) 401–415
www.elsevier.com/locate/ijpara

Bayesian spatial analysis of a national urinary schistosomiasis questionnaire to assist geographic targeting of schistosomiasis control in Tanzania, East Africa

A.C.A. Clements [a,*], S. Brooker [b], U. Nyandindi [c], A. Fenwick [d], L. Blair [d]

[a] Division of Epidemiology and Social Medicine, School of Population Health, University of Queensland, Herston Road, Herston, Qld. 4006, Australia
[b] Department of Infectious and Tropical Diseases, London School of Hygiene and Tropical Medicine, London, UK
[c] National Schistosomiasis and Soil-Transmitted Helminth Control Programme, Ministry of Health, Dar es Salaam, Tanzania
[d] Schistosomiasis Control Initiative, Department of Infectious Disease Epidemiology, Imperial College London, London, UK

Received 29 March 2007; received in revised form 26 July 2007; accepted 6 August 2007

Abstract

Spatial modelling was applied to self-reported schistosomiasis data from over 2.5 million school students from 12,399 schools in all regions of mainland Tanzania. The aims were to derive statistically robust prevalence estimates in small geographical units (wards), to identify spatial clusters of high and low prevalence and to quantify uncertainty surrounding prevalence estimates. The objective was to permit informed decision-making for targeting of resources by the Tanzanian national schistosomiasis control programme. Bayesian logistic regression models were constructed to investigate the risk of schistosomiasis in each ward, based on the prevalence of self-reported schistosomiasis and blood in urine. Models contained covariates representing climatic and demographic effects and random effects for spatial clustering. Degree of urbanisation, median elevation of the ward and median normalised difference vegetation index (NDVI) were significantly and negatively associated with schistosomiasis prevalence. Most regions contained wards that had >95% certainty of schistosomiasis prevalence being >10%, the selected threshold for bi-annual mass chemotherapy of school-age children. Wards with >95% certainty of schistosomiasis prevalence being >30%, the selected threshold for annual mass chemotherapy of school-age children, were clustered in north-western, south-western and south-eastern regions. Large sample sizes in most wards meant raw prevalence estimates were robust. However, when uncertainties were investigated, intervention status was equivocal in 6.7–13.0% of wards depending on the criterion used. The resulting maps are being used to plan the distribution of praziquantel to participating districts; they will be applied to prioritising control in those wards where prevalence was unequivocally above thresholds for intervention and might direct decision-makers to obtain more information in wards where intervention status was uncertain.

Keywords: Schistosomiasis; *Schistosoma haematobium*; Haematuria; Questionnaire; Spatial analysis; Bayesian modelling; CAR model; Disease control; Tanzania

1. Introduction

Recent estimates have put the number of people at risk of schistosomiasis at 779 million and the number actually infected at 207 million, the vast majority of whom are located in sub-Saharan Africa (SSA) (Steinmann et al., 2006). To help tackle schistosomiasis, new partnerships and global alliances have been formed, with a focus on preventative chemotherapy using praziquantel (World Health Organisation (WHO), 2006). In SSA, schistosomiasis has two forms: urinary schistosomiasis, caused by infection with *Schistosoma haemtatobium*, and intestinal schistosomiasis, caused by *Schistosoma mansoni*. Both forms have a focal distribution in endemic countries, which has been partly explained by a range of climatic, ecological and sociological factors (Brooker, 2007). Such focality means

* Corresponding author. Tel.: +61 (0) 7 32405952; fax: +61 (0) 7 32405540.
E-mail address: a.clements@uq.edu.au (A.C.A. Clements).

0020-7519/$30.00
doi:10.1016/j.ijpara.2007.08.001

that mass treatment with praziquantel needs to be targeted specifically at high-prevalence communities (Lengeler et al., 2002). Efficient, geographically targeted allocation of limited resources can be facilitated by, and represents the ultimate application of, spatial analysis in the context of parasitic disease control (Hay and Snow, 2006; Brooker and Utzinger, 2007).

Originally developed, administered and tested in Tanzania (Lengeler et al., 1991), questionnaires for self-reported urinary schistosomiasis have been adopted as a rapidly administered, low-cost alternative to parasitological screening of *S. haematobium* infection. They have been validated in a wide range of African settings (Ansell et al., 1997; Booth et al., 1998; Guyatt et al., 1999; Lengeler et al., 2000; Mafe et al., 2000), and are recommended by the WHO for identifying high-prevalence communities in need of mass treatment with anti-schistosomal drugs (Chitsulo et al., 1995). In 2004, the Tanzanian National Schistosomiasis and Soil-Transmitted Helminth Control Programme (NSSCP) conducted the first-ever national schistosomiasis questionnaire survey as part of its planning activities, collecting data from over two and a half million school children in all 21 mainland regions. This provided a unique opportunity to investigate spatial analysis as a tool for resource planning in a national control programme, using the largest schistosomiasis questionnaire study, and perhaps one of the largest tropical disease surveys, ever conducted.

In the current study, a ward-level Bayesian spatial analysis of the questionnaire data was conducted for self-reported schistosomiasis and self-reported blood in urine (BIU), a sensitive and specific clinical sign of urinary schistosomiasis, with the following aims: (i) to derive estimates of prevalence of schistosomiasis in Tanzanian wards that are robust to the influence of varying sample sizes; (ii) to identify clusters of wards with high and low prevalence of urinary schistosomiasis in order to facilitate future epidemiological investigations and geographic targeting of control programmes; and (iii) to quantify the uncertainty surrounding prevalence estimates in order to give decision-makers a more thorough understanding of risks associated with different resource allocation strategies, and to direct future data collection.

2. Materials and methods

2.1. Control programme

The NSSCP was established in 2003 with support from the Schistosomiasis Control Initiative (SCI, www.schisto.org). Details of the programme are provided in Kabatereine et al. (2006). The programme has responsibility for delivering mass treatment with praziquantel to high-prevalence areas in all 21 mainland regions. It classifies communities on the basis of prevalence of schistosomiasis in school-age children, according to three strategies: (i) in schools where prevalence is <10%, school-age children are treated once upon entering and once upon exiting primary school; (ii) in schools where the prevalence is 10–50%, mass treatment of all school-age children is conducted every other year; and (iii) in schools where the prevalence is >50%, mass treatment of all school-age children is conducted annually. The schistosomiasis morbidity questionnaire has been found to consistently underestimate the true prevalence of infection by approximately 20% (Ansell et al., 1997), leading to a recommendation that a prevalence of self-reported schistosomiasis of 30% be used to define communities where the true prevalence is expected to be above 50% and the NSSCP has adopted this recommendation. As soil-transmitted helminth infections are widespread in Tanzania, albendazole is co-administered with praziquantel. Treatment of school-age children commenced in 2005, in six north-western and five coastal regions.

2.2. Questionnaire data

The questionnaire survey is briefly described in Kabatereine et al. (2006) and more detail will be provided in a forthcoming paper, but here we summarize the main features. The survey was administered through the existing infrastructure of the Tanzanian National School Health Programme. District school health coordinators (DSHC) from the education and health departments were educated in how to train teachers to administer the questionnaire (Supplementary File 1) to students in primary school grades one, three and five. Questionnaires were distributed by DSHC to head teachers who, in turn, distributed questionnaires to teachers who administered the questionnaires. All students in eligible grades were asked whether they had experienced schistosomiasis (“kichocho” in Kiswahili) or BIU (“damu katika mkojo” in Kiswahili) in the previous 2 weeks. As with other schistosomiasis morbidity questionnaires, these questions were placed amongst several (in our case, 14) masking questions (e.g. “Did you have malaria in the last 2 weeks?”) to obscure the purpose of the survey and minimise bias. Responses (“yes”, “no” or “don’t know”) were entered into the questionnaire forms. Completed questionnaires were returned to the DSHC and they were subsequently passed back to the coordinator of the NSSCP. Responses were entered into a Microsoft Access database.

School-level prevalence of self-reported schistosomiasis and BIU were compared with parasitological data from 120 schools in four regions of north-western Tanzania (Clements et al., 2006a) and 27 schools in one region of coastal Tanzania (Tanga), and microhaematuria data in 58 schools in four other coastal regions. Prevalence based on parasitological or microhaematuria data was dichotomised according to the intervention thresholds. Area under the curve (AUC) of the receiver operating characteristic (ROC), a plot of sensitivity versus one minus specificity, was used as the test statistic for comparing the questionnaire prevalence to parasitological or microhaematuria prevalence and