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Mapping and modelling the geographical distribution of soil-transmitted helminthiases in Peninsular Malaysia: implications for control approaches

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Abstract. Soil-transmitted helminth (STH) infections in Malaysia are still highly prevalent, especially in rural and remote communities. Complete estimations of the total disease burden in the country has not been performed, since available data are not easily accessible in the public domain. The current study utilised geographical information system (GIS) to collate and map the distribution of STH infections from available empirical survey data in Peninsular Malaysia, highlighting areas where information is lacking. The assembled database, comprising surveys conducted between 1970 and 2012 in 99 different locations, represents one of the most comprehensive compilations of STH infections in the country. It was found that the geographical distribution of STH varies considerably with no clear pattern across the surveyed locations. Our attempt to generate predictive risk maps of STH infections on the basis of ecological limits such as climate and other environmental factors shows that the prevalence of *Ascaris lumbricoides* is low along the western coast and the southern part of the country, whilst the prevalence is high in the central plains and in the North. In the present study, we demonstrate that GIS can play an important role in providing data for the implementation of sustainable and effective STH control programmes to policy-makers and authorities in charge.

Keywords: mapping, geostatistical modelling, soil-transmitted helminths, Malaysia.

Introduction

Soil-transmitted helminth (STH) infections are among the most widespread human diseases, especially among those trapped in the vicious cycle of poverty and destitution in the tropics and subtropics (Hotez et al., 2009). Of particular importance are the two anthropophilic species of hookworm (*Necator americanus* and *Ancylostoma duodenale*), the roundworm *Ascaris lumbricoides* and the whipworm *Trichuris trichiura* (Chan et al., 1994). Although the annual worldwide mortality due to STH infections varies depending on the source (from 12,000 to 135,000) (WHO, 2005), these infections are the leading causes of malnutrition, growth stunting and cognitive deficit among vulnerable groups, such as children and women of reproductive age (WHO, 2005). It can be estimated that approximately one third of the world's population (~2 billion people) is currently infected with at least one STH species; 1.2 billion people with *A. lumbricoides*, 800 million with *T. trichiura* and 600 million with hookworm (de Silva et al., 2003; Bethony et al., 2006).

Malaysia has witnessed rapid socioeconomic growth and infrastructure development since independence 57 years ago. Nevertheless, the country is still plagued with parasitic diseases, in particular STH infections (Aaron et al., 2011; Ahmed et al., 2011; Ngui et al., 2011; Nasr et al., 2013). Summarising the studies conducted since the colonial era demonstrate that highly endemic foci remain largely unchanged with alarmingly high prevalence rates in poor and rural dwellers (Lim et al., 2009). The STHs are not notifiable diseases, and after the national deworming programme among school-aged children was discontinued in 1983 (Anon, 1985), little effort has been made towards combatting these infections; one of the reasond may be that a precise account of the total STH burden in the country is not available. Most of the information in this field is scattered across the scientific literature and not systematically catalogued.

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In recent years, however, there has been renewed interest in STH control from international aid organisations leading to increased momentum in attaining more comprehensive data and allowing available control resources to be more rationally and cost-effectively deployed (Brooker and Michael, 2000). As a result of changes in health priorities, tremendous efforts have been made in the development of methods to map the distribution of STH infections, particularly through the use of geographical information systems (GIS) and remote sensing technologies. Most activities with respect to STH mapping have been attempted in African countries (Knopp et al., 2008; Brooker et al., 2009; Snow et al., 2009; Pullan et al., 2011; Tchuem Tchuenté et al., 2012). In addition, this approach has recently been used to model the geographical distribution of STH infections in Bolivia (Chammartin et al., 2013) and Southeast Asia (Brooker, 2002; Brooker et al., 2003).

In the context of a preventive deworming programme, reliable and accurate contemporary maps offering intervention recommendations at a realistic scale are needed to minimise the cost of interventions. The establishment of reliable predictive risk maps for STH infections in Malaysia is imperative for developing and implementing sustainable control measures when recourses are finite and limited. We attempt here to generate such maps not only on the basis of empirical survey data, but also by applying logistic regression analysis for the potential effect of climate and other environmental factors. Through investigation of ecological correlations, we planned to identify STH distribution, prioritise target areas and estimate the population at risk and its implications for the STH control programme in Malaysia.

Materials and methods

Data searches

Relevant information on the prevalence of STH infections in Malaysia were identified through a combination of: (i) an extensive search in electronic bibliographic databases; (ii) manual search of local archives and libraries; and (iii) direct contact with local researchers. In brief, an initial systematic search of published articles started in 2008 and was repeated periodically between 2009 and 2012. The online electronic databases PubMed, ISI Web of Knowledge, Google and Yahoo were used to identify relevant studies for STH by using the Medical Subject Headings (MSHs) hookworm, ascariasis, trichuriasis, *Necator americanus*, *Ancylostoma duodenale*, *Ascaris lumbricoides*, *Trichuris trichiura*, intestinal parasites or soil-transmitted helminth (STH) together with Malaysia with no restriction of publication date and language. The second search strategy involved the identification of "grey" literature sources such as university theses, unpublished surveys conducted by government institutions and Ministry of Health (MoH) archives. The third source of information included personal contact with researchers known to have undertaken STH surveys in Malaysia. In addition, cross-sectional surveys were conducted between 2008 and 2012 in order to determine the prevalence of STH infections in several locations in Peninsular Malaysia.

Geo-positioning procedures

The geographical coordinates of various surveyed locations were determined using combination of various free, on-line electronic resources including GeoNet Names Server (http://earth-info.nga.mil), Google Earth (http://www.google.com), Wikimapia (http://www.wikimapia.org), Maplandia (http://www.maplandia.com) and Tageo (http://www.tageo.com). Each of the identified locations from one source was consequently cross-checked against other sources to ensure consistency of the identified coordinates. For the field investigation survey conducted by our group, the location coordinates were recorded using a global positioning system (GPS) approach with a hand-held Garmin GPSMAP 60CSx instrument. The recorded coordinates were then downloaded from the GPS memory card into a computer using GPS Pathfinder software (http://www.trimble.com/mappingGIS/PathfinderOffice.aspx). All the digital data coordinate system were synchronised using World Geodetic System (WGS, 1984) according to longitude and latitude.

Selection and entry

Pre-determined inclusion and exclusion criteria were applied to information identified through the above search mechanisms. Only cross-sectional surveys were included in the database. Multiple surveys from the same location but surveyed at different times were included as separate entries. Data from hospitals and related, clinical surveys were excluded. Survey data were also excluded if the prevalence was reported without denominator (i.e. sample size and number of positive samples) or if there were inconsistencies or errors in the calculations presented. Surveyed locations that could not be geo-positioned were also