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A socioenvironmental composite index as a tool for identifying urban areas at risk of lymphatic filariasis

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Summary

OBJECTIVE To describe the spatial distribution of lymphatic filariasis and its relationship with the socioenvironmental risk indicator, thus identifying priority localities for interventions in endemic urban areas.
METHODS The study area was the municipality of Jaboatão dos Guararapes, State of Pernambuco, Brazil. The data sources were a parasitological survey and the 2000 demographic census. From these data, a socioenvironmental composite risk indicator was constructed using the 484 census tracts (CT) as the analysis units, based on the score-formation technique. Census tracts with higher indicator values presented higher risk of occurrences of filariasis.
RESULTS Six thousand five hundred and seven households were surveyed and 23 673 individuals were examined, among whom 323 cases of microfilaremia were identified. The mean prevalence rate for the municipality was 1.4%. The indicator showed that 73% (237/323) of the cases of microfilaremia were in high-risk areas (third and fourth quartiles) with worse socioenvironmental conditions (RR = 4.86, CI = 3.09–7.73, $P < 0.05$).
CONCLUSIONS The socioenvironmental composite risk indicator demonstrated sensitivity, since it was able to identify the localities with greater occurrence of infection. Because it can stratify spaces by using official and available data, it constitutes an important tool for use in the worldwide program for eliminating lymphatic filariasis.

keywords epidemiology, lymphatic filariasis, social conditions, risk index

Introduction

Lymphatic filariasis (LF) is considered to be one of the principal neglected diseases (Perera *et al.* 2007) because of its wide geographic distribution in poor areas and the individual and collective social, physical and economic losses caused (WHO 2000; Ottesen 2006). Today, 81 countries are considered to be endemic for this disease. It is estimated that 1.3 billion people live in risk areas and 120 million people are currently infected (Ottesen *et al.* 1997, 2008; WHO 2008).

In Brazil, LF transmission occurs only in urban areas. It exists in three municipalities in the Metropolitan Region of Recife, State of Pernambuco: Recife, Jaboatão dos Guararapes and Olinda (Medeiros *et al.* 1999). It is estimated that three millions people live in these endemic areas and, of these, 49 000 are thought to be infected (Ministry of Health 2000).

In this region, the area with endemic disease seems to be expanding. Autochthonous cases of microfilaremia (infected within the municipality) have been reported in another five municipalities: see Figure 1 (Medeiros *et al.* 1999, 2006; Ministry of Health 2000). A survey conducted in the municipality of Jaboatão dos Guararapes observed microfilaremia prevalence rates of up to 5.15% in the Cavaleiro district and 2.9% in the Jaboatão district (Bonfim *et al.* 2003; Medeiros *et al.* 2008).

Because new control strategies for LF have expanded and become available, elimination of this disease has been considered feasible (CDC 1993). Consequently, WHO has drawn up a proposal to eliminate LF as a public health problem around the world (Ottesen *et al.* 1997; Maher &

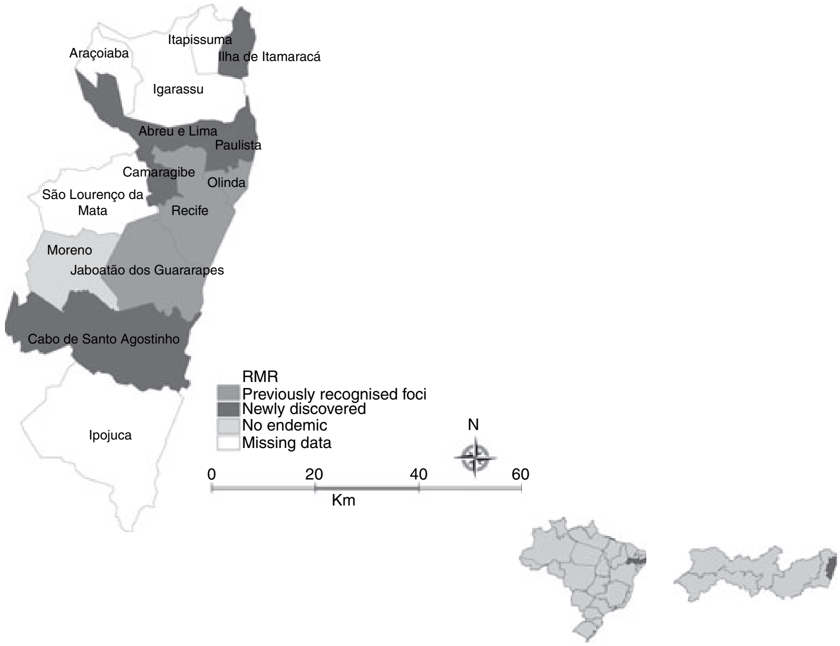

Figure 1 Distribution of autochthonous cases of Lymphatic filariasis in the Metropolitan Region of Recife, State of Pernambuco, Brazil.

Ottesen 2000). One important requirement for national elimination programs is that information should be available regarding the spatial extent and transmission risk of the infection, to facilitate adequate planning for control and elimination (Lindsay & Thomas 2000; Sabesan *et al.* 2006; Ngwira *et al.* 2007; Molyneux 2009).

One of the main intervention strategies encouraged by WHO consists of the use of mapping to delimit the endemic areas, as a prerequisite for planning LF elimination programs (Hassan *et al.* 1998a,b; Sabesan *et al.* 2000; Gyapong *et al.* 2002; Srividya *et al.* 2002; Sherchand *et al.* 2003). Based on the worldwide proposal, the Brazilian Ministry of Health has implemented the National Lymphatic Filariasis Elimination Program. One of the main strategies is to determine the areas at risk, so that these can be given priority in implementing the program (Ministry of Health 1997).

Lymphatic filariasis has traditionally been considered to be a disease associated with poverty, inadequate sanitation and underdevelopment (Galvez Tan 2003; Durrheim *et al.* 2004; Gbakima *et al.* 2005; Sabesan *et al.* 2006; Streit & Lafontant 2008). Braga *et al.* (2001) evaluated a socioenvironmental indicator constructed with a scoring methodology formed by three variables (% households not connected to the sanitation network, % of households with inadequate destination of waste and average of people per bedroom) to stratify areas in the city of Olinda, Brazil. Construction of a socioenvironmental composite risk indicator could make it possible to develop a model capable of characterizing this association and spatially identifying areas of greater risk, i.e. priority areas for interventions.

A socioenvironmental composite risk indicator (SRI) is a measurement that combines different socioeconomic and environmental variables, to analyze the characteristics of population groups living in given urban spaces (Carstairs & Morris 1989; Souza *et al.* 2000, 2007; Niggebrugge *et al.* 2005; Forastiere *et al.* 2006; Havard *et al.* 2008; Sánchez-Cantalejo *et al.* 2008). Composite numbers are unitless numbers that combine various indicators or statistics to reveal a complex social reality (United Nations 2007). To find which areas present greater risk, the indicator reflects differences in living conditions relating to the social organization of the space and, consequently, differences in the filariasis transmission risk. Thus, the indicator is expected to be capable of identifying the risk conditions relating to adverse social and environmental factors, which are important with regard to maintenance and expansion of the areas presenting filariasis (Albuquerque & Morais 1997). The aim of the present study was to describe the spatial distribution of LF and its relationship with the SRI.

Methods

Parasitological survey

The study area consisted of the municipality of Jaboatão dos Guararapes, which has a total area of 256 km^2 and forms part of the Metropolitan Region of Recife in northeastern Brazil. The municipality has 27 districts and 492 census tracts (CTs). Two of these districts and eight CTs were excluded from the study because no information was available. Thus, 25 districts and 484 CTs were evaluated.

The minimum sample size (5915 households) was estimated based on the total number of households recorded in the last census (111 666), assuming that 6% of them would harbour at least one microfilaremic individual (Bonfim *et al.* 2003) and that no more than 5% of the subjects within each 95% confidence interval would be misclassified as microfilaremic when they were not, or vice versa.

Although only a 12-household sample was needed in each of the 484 CTs to produce the minimum sample, 14 households were registered in each CT to allow for possible refusals to participate. These 14 households per CT were selected based on the maps used in the last national census. The map of each CT was divided into four quadrants and then a straight line bisecting the second and third quadrants was drawn. The heads of the seven households on each side of the street at the midpoint of this line were then approached, told about the survey methodology and aims, and asked to give their informed consent.

A fingerprick sample of about 50 μl was then collected from each consenting member of each study household, between 23:00 and 01:00 h (Dreyer *et al.* 1996). These samples were used to prepare thick smears, which were Giemsa-stained and then checked under an optical microscope for microfilariae of *W. bancrofti*. All the subjects who were found to be microfilaremic were treated with diethylcarbamazine (WHO 1994). Twenty eight thousand and six hundred and twelve people were registered to participate in the survey, of whom 4939 (17.26%) did not undergo the test.

The CTs were classified according to the microfilaremia prevalence rates: <5% was defined as hypoendemic; 5 to 10%, mesoendemic; and >10%, hyperendemic (WHO 1988). Differing from other types of filariasis, for which clearly defined criteria exist for characterizing endemic areas, there is no universally accepted definition for bancroftosis. Thus, it was decided that the WHO criteria would be most suitable for our region, as recommended by Albuquerque and Morais (1997).

The data collected were stored and analyzed using EPIINFO version 6.04d (http://www.cdc.gov). Statistical comparisons were made using Student's *t*-test, whenever appropriate. A *P*-value of <0.05 was considered indicative of a statistically significant difference. This study was approved by the Ethics Committee of the Centro de Pesquisas Aggeu Magalhães, Fundação Oswaldo Cruz, in Recife.

Socioenvironmental composite risk indicator

To construct the SRI, data from the 2000 demographic census were used, which were made available by the Brazilian Institute for Geography and Statistics (IBGE). The analysis unit used was the CTs, which were the geographic units for collecting the IBGE data (IBGE 2001). The cartographic base was obtained from the municipal digital network, also made available by the IBGE, which accompanied the census information database. The maps were produced using the TERRAVIEW free software, version 3.1.4 (http://www.dpi.inpe.br/terraview/index.php).

The SRI was constructed based on the score-formation technique (UNDP 1999). The following variables were selected: proportion of households without water supplied from the general network; proportion of households without sanitary drainage connected to the general sewage or rainwater network; proportion of households without garbage collection performed by the cleansing services; proportion of heads of households without income; and proportion of heads of households without any school education. This information was aggregated per CT and was calculated as absolute values in order to then extract the percentage occurrence. The scores ranking the CTs were obtained from these percentage occurrences.

The CT presenting the highest occurrences for each of the variables considered received a score of one. The CT with the lowest occurrence for each of the variables was given a score of zero. The scores for the other CTs were constructed per variable from the following equation:

$$S_{ij} = (\mathrm{OC}_{ij} - \mathrm{OC}_{\min j})/(\mathrm{OC}_{\max j} - \mathrm{OC}_{\min j})$$

Where '*i*' represents the CT and '*j*' the variable; S_{ij} = score for CT '*i*' in relation to the variable '*j*'; OC_i = occurrence recorded for the variable '*j*' in CT '*i*'; $\mathrm{OC}_{\min j}$ = minimum occurrence of the variable '*j*', noted among the different CTs; $\mathrm{OC}_{\max j}$ = maximum occurrence of the variable '*j*', noted among the different CTs.

The aim in obtaining these scores was to determine the relative occurrence, taking the highest and lowest observations as the parameters. The SRI for each CT was then calculated as the arithmetic mean of the scores recorded, i.e. $\mathrm{SRI}_i = \Sigma_j S_{ij}/n \times 100$, where '*n*' was the number of variables selected as determinants for the occurrence of filariasis. SRIi was obtained as a mean, per line of the observations. The SRI was interpreted such that higher values (in percentages) indicated that the CT presented a higher risk of occurrences of filariasis.

The relationship between filarial infection prevalence and the SRI was analyzed using logistic regression. The equation below represents the adjusted model that was taken to explain the SRI.

$$\log(\pi/1 - \pi) = -3.83 + 0.015545\,\mathrm{SRI}$$

Results

Parasitological survey

The survey included 6507 households, and 23 673 individuals of both sexes aged 1 to 99 years were examined. From this, 323 cases of microfilaremia were identified, representing a mean prevalence rate for the municipality of 1.4% (Table 1).

Microfilaremia occurred in all age groups and both sexes, with predominance among males (2.0% male *vs*. 0.9% female; $P < 0.001$). The highest prevalence among males was in the age group of 20 to 29 years (3.7%) and for females, 10 to 19 years (1.7%) (Table 1).

In 255 (3.9%) of the 6507 households surveyed, one or more individuals with microfilaremia were found. With regard to the CTs, 28.1% (136/484) had one or more cases of microfilaremia, with prevalence rates ranging from 0 to 25%. Figure 3a characterizes the distribution of the microfilaremia prevalence rates and classifies the prevalence as hyperendemic, mesoendemic or hypoendemic.

Socioenvironmental composite risk indicator

The CTs were ranked in decreasing order and grouped according to the quartile distribution, following the calculated values for the SRI. Thus, a ranking of the different potential risk conditions for filariasis occurrence was obtained (Table 2). Figure 2 shows that there was a positive association between the SRI and the prevalence of filarial infection.

The low-risk stratum (first quartile) grouped the CTs with the best socioenvironmental conditions; the medium-risk stratum (second quartile) reflected an intermediate situation; and the high-risk stratum (third and fourth quartiles) grouped the worst socioenvironmental conditions among the population living in the municipality (Figure 3b). Around 73% (237/323) of the filariasis cases were situated in the high-risk stratum (Table 2). From the

Table 2 Prevalence of microfilaremia according to socioenvironmental composite risk strata, Jaboatão dos Guararapes, Pernambuco, Brazil

Stratum	Individuals examined	Positive findings	Prevalence
Low risk	5510	22	0.40
Medium risk	5955	64	1.07
High risk	12208	237	1.94

χ^2 61.23, Prevalence ratio 4.86 (CI 3.09–7.73), $P < 0.05$.

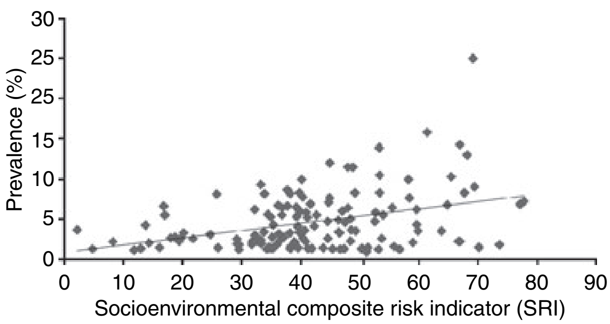

Figure 2 Dispersion between the prevalence rate for filarial infection and the SRI. Note: census tracts that did not present any cases of filarial infection have been excluded.

Table 1 Prevalence of microfilaremia according to age group and sex in Jaboatão dos Guararapes, Pernambuco, Brazil

	Female					Male					Total							
	Positive		Negative		Total	Positive		Negative		Total	Positive		Negative		Total			
Age group	*N*	%	*N*	%	*N*	*N*	%	*N*	%	*N*	*N*	%	*N*	%	*N*	OR	χ^2	*P*-value
1–9	5	0.3	1.849	99.7	1.854	6	0.3	1.800	99.7	1.806	11	0.3	3.649	99.7	3.660	0.81 (0.22–3.00)	0.00	0.96
10–19	48	1.7	2.814	98.3	2.862	49	1.8	2.630	98.2	2.679	97	1.8	5.444	98.2	5.541	0.92 (0.60–1.39)	0.10	0.74
20–29	25	1.0	2.371	99.0	2.396	68	3.7	1.747	96.3	1.815	93	2.2	4.118	97.8	4.211	0.28 (0.17–0.45)	32.11	0.00
30–39	16	0.7	2.202	99.3	2.218	41	2.9	1.373	97.1	1.414	57	1.6	3.575	98.4	3.632	0.24 (0.13–0.45)	25.4	0.00
40–49	10	0.6	1.764	99.4	1.774	16	1.4	1.099	98.6	1.115	26	0.9	2.863	99.1	2.889	0.39 (0.16–0.91)	4.96	0.02
50–59	7	0.6	1.082	99.4	1.089	12	1.6	720	98.4	732	19	1.0	1.802	99.0	1.821	0.39 (0.14–1.07)	3.22	0.07
60–99	6	0.5	1.165	99.5	1.171	13	1.9	683	98.1	696	19	1.0	1.848	99.0	1.867	0.27 (0.09–0.76)	6.74	0.00
Unknown	–	–	22	100	22	1	3.3	29	96.7	30	1	1.9	51	98.1	52	–	–	–
Total	117	0.9	13.269	99.1	13.386	206	2.0	10.081	98.0	10.287	323	1.4	23.350	98.6	23.673	0.44 (0.35–0.55)	52.66	0.00

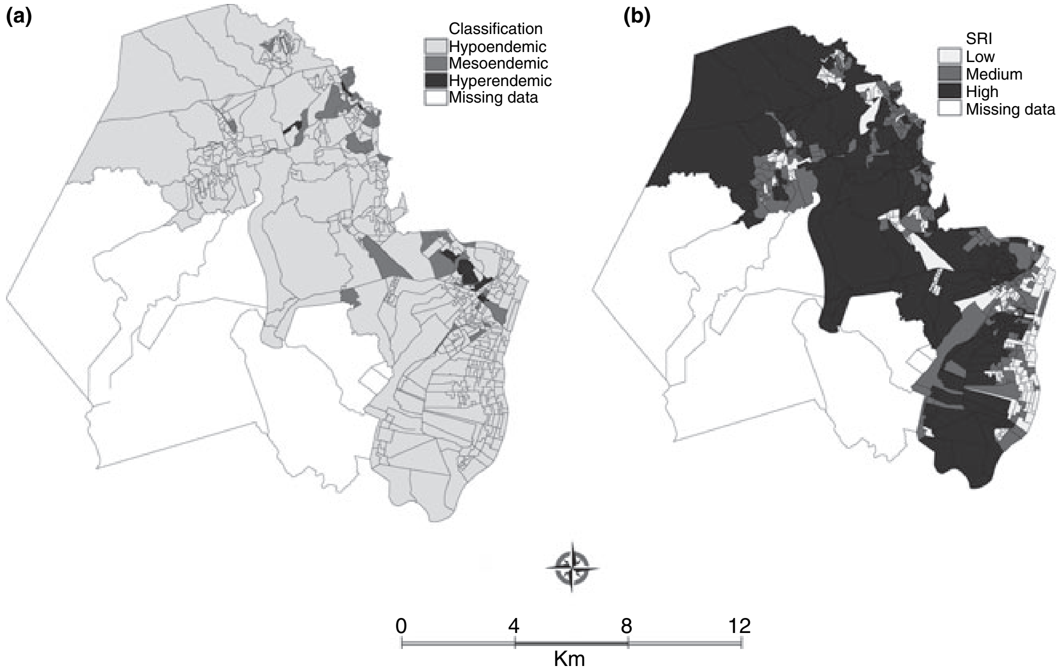

Figure 3 (a) Classification of the microfilaremia prevalence rate according to census tracts. (b) Distribution of risk strata for census tracts according to the socioenvironmental risk indicator (SRI). Municipality of Jaboatão dos Guararapes, Pernambuco, Brazil.

prevalence ratio calculation, the high-risk stratum presented a risk of 4.86 (Table 2).

The logistic model presented a residual deviation of 151.06 for 134 degrees of freedom (P = 0.1489), thus indicating that the model fitted well. The residual and diagnostic analysis corroborated the goodness-of-fit test, thus indicating a good level of fit. An increase in the SRI implied an increase in the prevalence of infected cases of approximately 1.6%.

Discussion

The results from the epidemiological survey indicate that filariasis is endemic in the municipality. The mean prevalence rate for microfilaremia was 1.4%, but when analyzed according to CTs, the rates obtained ranged from 0 to 25%. From the WHO classification, some areas of the municipality were seen to be hyperendemic (>10%). As in other endemic areas, the distribution of cases of filarial infection was shown to be focal in the municipality (Albuquerque *et al.* 1995a; Ramzy *et al.* 1999). The infection pattern was similar to previous descriptions in the literature: men of around 29 years of age were affected most (Brabin 1990).

The proposal to construct a risk indicator takes into account the relationship between socioenvironmental conditions and the transmission of LF (Albuquerque & Morais 1997; Braga *et al.* 2001). This indicator was constructed using variables relating to basic sanitation, income and schooling level, because of their importance in relation to filariasis transmission and, especially, because of the link that exists between these and the population's quality of life (Braga *et al.* 2001).

Culex quinquefasciatus is the vector mosquito in the municipalities of Recife, Jaboatão dos Guararapes and Olinda (Medeiros *et al.* 1992). It is adapted to urban areas, especially those with high population densities and poor living conditions (lack of basic sanitation, insufficient water supply and inadequate housing). These conditions favour its proliferation (Mott *et al.* 1990; Albuquerque 1993). In the municipality of Jaboatão dos Guararapes, only 21.1% of homes are served by a sewage collection system (IBGE 2001).

Mwobobia and Mitsui (1999) studied socioeconomic and demographic factors implicated in controlling LF in the Kwale district, a rural area in Kenya. They found that better education and employment of the head of the household were the factors positively associated with the use of protection against the vector. Baruah and Rai (2000) correlated house construction standards with the density of *C. quinquefasciatus* and transmission of bancroftosis in Varanasi, an urban area in India. They found that poorly constructed houses played an important role in the vector density, by increasing the possibility of infection inside these homes and maintaining greater potential for filariasis transmission among this population.

Furthermore, needy populations are in a worse situation for adopting individual protection measures. Some studies have demonstrated the importance of using mosquito nets, especially those impregnated with insecticides, for preventing filariasis (Prybylski *et al.* 1994; Bogh *et al.* 1998; Pedersen & Mukoko 2002; Odermatt *et al.* 2008; Vijay Kumar & Ramaiah 2008). In Brazil, Albuquerque *et al.* (1995b) found that 49.6% of the population surveyed in an urban area in Recife regularly used mosquito nets for sleeping. They observed a significant association between not using a mosquito net and presence of microfilaremia.

The results from the present study provide a picture of the distribution of filarial infection prevalence within urban spaces. They identify priority groups for epidemiological surveillance actions and filariasis elimination programs. The data presented in Table 2 demonstrate the sensitivity of the indicator proposed: the highest prevalence rate was found in the CT that presented the highest SRI (highest risk), while the lowest prevalence rate was found in the quartile that grouped the lowest SRI (lowest risk).

The importance of the spatial distribution for controlling LF is demonstrated through studies on the issues of population sampling and data modelling (Gyapong & Remme 2001; Gyapong *et al.* 2002; Srividya *et al.* 2002). Studies analyzing the relationship between endemicity and the social and environmental variables show the importance of spatial delimitation for rural areas at risk (Hassan *et al.* 1998a; Mwobobia & Mitsui 1999; Lindsay & Thomas 2000; Hassan 2004; Sabesan *et al.* 2006; Sowilem *et al.* 2006; Ngwira *et al.* 2007) and urban areas at risk (Baruah & Rai 2000; Boyd *et al.* 2004). Considering the association between LF and socioenvironmental variables, the present study showed that increasing SRI (worsening socioenvironmental conditions) implied an increase in the prevalence of infected cases of approximately 1.6%.

The model adopted in this study has made it possible to analyze the distribution of cases of microfilaremia from the perspective of collective risk. The analysis demonstrated that 73.37% of the cases identified were located in the stratum of highest risk, i.e. the worst social conditions. This shows the sensitivity of the SRI for identifying geographic areas at risk of occurrences of LF. Moreover, the results demonstrate that worse health conditions were associated with social disparities. Higher prevalence rates were situated in the strata of worse socioenvironmental conditions.

This indicator presents the advantage of being able to use existing data, such as the national demographic census, thus diminishing the operational costs involved in data collection. It could easily be used as a tool in the worldwide elimination program, for mapping out priority areas for interventions, which is a necessary prerequisite for adequate planning with regard to control and elimination.

The sensitivity of the SRI was demonstrated in this study. It was able to map out the localities with greatest occurrences of cases in an endemic area. The indicator made it possible to stratify the space, using official and available data, thereby constituting a tool that could be used in filariasis control programs. The worldwide program for eliminating LF needs to identify the priority areas for interventions, and the indicator has the capacity to identify areas with high rates of infection and also areas with low prevalence of filariasis but with very poor living conditions. The latter should also be included in mass treatment programs, since such areas present socioenvironmental conditions capable of maintaining transmission.

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