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SPECIAL THEME: INEQUALITY

Inequality and leprosy in Northeast Brazil: an ecological study

Ligia Regina Sansigolo Kerr-Pontes,[1] Ana Cláudia Dorta Montenegro,[1] Maurício Lima Barreto,[2] Guilherme Loureiro Werneck[3] and Hermann Feldmeier[4]

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Background Leprosy is an important public health problem in many developing countries and many features of its determinants are still obscure.

Methods To investigate whether the incidence of leprosy is related to certain environmental and socioeconomic determinants, an ecological study was undertaken in 165 municipalities of the state of Ceará, Brazil. Social, economic, education, sanitation, demography, meteorology, and health data were collected. The dependent variable was the average incidence rate of leprosy from 1991 to 1999. Simple and multiple linear regressions were performed to assess the relationship between the dependent and the independent variables.

Results The average incidence rate for all the municipalities for the 1991–1999 period, varied from 0.06 to 14.68 per 10 000 persons per year. The level of inequality (β = 1.67, P = 0.011), the mean years of study among the population ≥25 years old (β = 1.35, $P < 0.001$), the population growth from 1991 to 1996 (β = 0.02, P = 0.007), the percentage of children 7–14 years old that did not go to the school (β = 0.02, P = 0.028), and the presence of a railroad in the municipality (β = 0.45, P = 0.038) were found to be predictors of the incidence rate of leprosy in Ceará.

Conclusion Our findings fit the assumption that, in Ceará, leprosy is associated with a high level of poverty and uncontrolled urbanization. We put forward the hypothesis that urbanization increases not only social inequality eventually leading to strong polarization, but also excludes people from social and material opportunities. Apparently, such deprivations render them susceptible for leprosy.

Keywords Leprosy, ecological study, inequality, Brazil

Leprosy is an important public health problem in developing countries and many features of its determinants are still obscure.[1] It is assumed that person-to-person transmission occurs under circumstances such as crowding, inadequate housing, and lack of hygiene,[2,3] and that certain immunogenetic polymorphisms confer susceptibility to infection with *Mycobacterium leprae*.[4–6] However, neither person-to-person transmission nor genetic predisposition explains sufficiently the patchy distribution of new cases.[7]

Under certain circumstances, *M. Leprae* occurs and can persist for months in the environment.[8,9] A study carried out in Indonesia showed that the presence of *M. leprae* in the environment is related to high prevalence of leprosy in the population.[10] Even considering that patient contact is the major determinant in incident leprosy[11] it is impossible to detect any contact in a great proportion of new leprosy cases.[12] Furthermore, the possibility of animal and environmental reservoirs of *M. leprae* has not been excluded.[13] The highly probable persistence of *M. leprae* in the environment has been suggested as a possible explanation for continuing high incidence rates despite effective multidrug therapy.[14]

[1] Departamento de Saúde Comunitária, Faculdade de Medicina, Universidade Federal do Ceará, R: Prof. Costa Mendes, 1608—5o. Andar, CEP: 60.190–080—Fortaleza—CE, Brazil.

[2] Instituto de Saúde Coletiva, Universidade Federal da Bahia, Rua Padre Feijó, 29—Canela—Centro Pediátrico Prof. Hosanah de Oliveira, CEP: 40110–170—Salvador—BA, Brazil.

[3] Instituto de Medicina Social, Universidade do Estado do Rio de Janeiro—NESC/UFRJ, Rua São Francisco Xavier, 524, pavilhão João Lyra Filho, 7o andar, blocos D—Maracanã, CEP 20559–900—Rio de Janeiro—RJ, Brazil.

[4] Fachbereich Humanmedizin, Freie Universität Berlin, Fabeckstr 60–62, 12203—Berlin, Germany.

Correspondence: Ligia Regina Sansigolo Kerr-Pontes, Departamento de Saúde Comunitária, Faculdade de Medicina, Universidade Federal do Ceará, R: Prof. Costa Mendes, 1608—5o. Andar, CEP: 60.190–080—Fortaleza—CE, Brazil. E-mail: ligia@ufc.br

Previous studies suggested that the incidence rates of leprosy are greater in rural than in urban areas.[7,15,16] However, uncontrolled urbanization, resulting from intense migration from rural areas, might also place urban populations at risk for developing leprosy. This situation is increasingly common in some Brazilian areas, particularly in the Northeast of the country.

In Ceará, Brazil, one of poorest states of the federation, the geographical distribution of leprosy is extremely heterogeneous. Despite a state-wide control programme implemented in the 1990s, the incidence rate of leprosy increased from 0.9 to 3.6 cases per 10 000 inhabitants from 1984 to 1998.[17] There are many municipalities with prevalence rates of less than 0.1 per 10 000 inhabitants and a few with prevalence rates as high as 25 per 10 000 people.[18] Interestingly, municipalities with very high prevalence rates are usually surrounded by others with high and/or intermediate prevalence rates.[19]

Effective control of leprosy, or in other words, reduction of incidence, would be more easily achieved if the epidemiology of the disease could be better understood. To investigate whether the incidence of leprosy is related to certain environmental and socioeconomic determinants an ecological study was undertaken in 165 municipalities of the state of Ceará.

Methods

Study area

The Northeast of Brazil has a semi-arid climate and regularly suffers from droughts. It is one of the poorest and less developed regions and contains 9 of the 27 states of the federation. Fifty-four per cent of the population live in poverty.[20] In 1999, the infant mortality rate and the illiteracy rate among people ≥15 years old was estimated as 53.0 per 1000 live births and 26.6%, respectively, whereas in the South of Brazil these indicators were 20.7 per 1000 and 7.8%, respectively. The Northeast is further characterized by important social and economic inequalities. While 50% of the population earns only 15.7% of the total income of the region, the share of the richest 1% is 16%.[17]

Ceará is located in the centre of the Northeast and is one of the three states of the region that shows the highest level of income inequality.[17,21] It has a population of around 7.5 million. Only 3.7% of the population earn more than US$450 per month. About 28% of people >15 years old are illiterate. As to general poverty it ranks third in the Northeast.[17]

Data sources

Social and economic data were obtained from the 1991 Brazilian census. Due to the long incubation period of leprosy, we decided to use these data as it is conceivable that variables from the recent past reflect risk factors for the transmission of *M. leprae* much better than current ones.

In 1991 the state of Ceará had 178 municipalities, of these 165 were included in the study. Thirteen municipalities did not report a single leprosy case during the study period. We decided to exclude these municipalities from the analysis because we strongly suspected that an incidence rate of zero was highly unlikely. The assumption that these municipalities simply forgot to report leprosy patients is supported by the fact that they notoriously failed to report data on other infectious diseases as well.

Variables included in this study were:

Socioeconomic: the degree of income inequality (defined as the degree of inequality in income distribution as measured by the Theil's L index—it can vary from 0 to 1, nearest to 1 indicating the greatest the level of inequality),[22] and the percentage of the heads of the household with a monthly income of less than half of the official minimum wage in 1991.

Education: mean years of study (schools and higher education) among the population >25 years and percentage of children 7–14 years old who did not go to school in 1991.

Sanitation: percentage of households with a public water supply in 1991.

Demography: the relative percentage of population growth of each municipality from 1991 to 1996; the percentage of households with a population density >2 people per room in 1991.

Meteorology: data on annual rainfall were obtained from the Fundação Cearense de Metereologia (FUNCEME).

Health: Infant Mortality Rate in 1991; number of physicians per 1000 inhabitants in 1991; number of public health services per 1000 inhabitants in 1991.

We also investigated if the municipality had been linked to or was near to a railroad in 1991. This was chosen as an indicator of accessibility to the municipality, i.e. whether it was probable that people and merchandise could have moved in and out easily.

The dependent variable was the average incidence rate of leprosy from 1991 to 1999 and was extracted from the records of the Department of Health of Ceará State.[23] The variable was calculated as follows. For each calendar year from 1991 to 1999 and for each municipality, the number of new leprosy cases and the mid-year population (interpolated by using a geometric growth equation using population data from the 1991 and 2000 census's) were used to calculate incidence rates. Thus, for each municipality, the average incidence rate over the 9 years was calculated by summing the number of new leprosy cases and dividing it by the sum of mid-year population estimates. We preferred to use the average incidence rates over yearly incidence rates in order to provide more stable rates. Besides, it was supposed that variances in the incidence of new cases within a municipality could arise due to operational factors, e.g. leprosy programme personnel left the municipality health department and were not replaced for a prolonged period, which in turn would have an impact on the annual detection rate. As incidence data were obtained from a state registry and under-reporting of cases from the municipality of the Ministry of Health cannot be excluded, true incidences might be higher than those used for statistical analysis. However, we assumed that the effect is similar for the 165 municipalities analysed.

Data analyses

Pearson's correlation coefficient was calculated to assess the relationship between the independent and each dependent variable, and simple and multiple linear regressions were also performed. Based on the Wald test, variables with an associated level of significance of at least 5% in the simple regression model were selected to remain in the final model. We used residual diagnostics to check for the regression assumptions.

Since the dependent variable was not normally distributed, a logarithm transformation was performed. For all calculations Stata 7.0™ software was used.

Results

The average incidence rate for all the municipalities for the 1991–1999 period varied from 0.06 to 14.68 per 10 000 persons per year.

Some of the independent variables showed a high degree of variation among the municipalities (Table 1). About 10% of the municipalities had a Theil's L index greater than 0.70, a value near 1.0 indicating the greatest possible degree of inequality. Half of the municipalities had ≥40% of the heads of families earning half the minimum wage per month or less. The mean years of study among the population ≥25 years old was 1.9, i.e. the great majority of the adults had not even finished the second degree of the elementary school. No municipality had more than 10% of its inhabitants with more than 11 years schooling and three-quarters of the municipalities had more than a third of children between 7 and 14 years out of school. For one-quarter of the municipalities, no water supply was available for more than 60% of the household, and for the same proportion of municipalities their populations decreased from 1991 to 1996. Only 10% of the municipalities had at least one physician per 1000 inhabitants.

Income inequality, the relative population growth of the municipality, educational achievement, and the number of physicians per 1000 inhabitants were found to be correlated to the incidence rate of leprosy. We also found significant correlations between various dependent variables (Table 2).

The level of inequality ($\beta = 1.67$, $P = 0.011$), the mean years of study among population aged ≥25 years ($\beta = 1.35$, $P < 0.001$), the population growth from 1991 to 1996 ($\beta = 0.02$, $P = 0.007$), the percentage of children 7–14 years old that did not go to the school ($\beta = 0.02$, $P = 0.028$), and the presence of a railroad in the municipality ($\beta = 0.45$, $P = 0.038$) were found to be predictors of the incidence rate of leprosy in Ceará (Table 3).

Figure 1 shows the state railroad distribution and leprosy incidence during the study period. We observed that municipalities with access to railroads are frequently the same as those with the greatest incidence of leprosy.

Discussion

The World Health Organization has set a goal of eliminating leprosy as a public health problem from the year 2000. To achieve this goal multidrug therapy has been advocated for all areas where leprosy is endemic. Although multidrug therapy has been used almost world-wide for many years, leprologists are confronted with the observation that global prevalence rates are on a steady decrease.[1,7] This can be explained by shortening of the multidrug therapy and the 'cleaning' of registers. Otherwise, incidence rates have increased during the last decade. Several studies suggest that both increased transmission and increased detection are the cause of the growth of the incidence rate in Brazil.[24–26]

Systematic control operations have been implemented since the 1990s in Brazil. However, the country is responsible for 80% of all leprosy cases that occur in Latin America, and it is the second most important endemic area in the world after India.[27] Ceará, a member of the so-called poverty belt in Northeast Brazil, is a typical example of where, despite ongoing

Table 1 Socioeconomic characteristics, health indicators, and other variables of 165 municipalities in the study period[a]

	Mean	SD	Minimum	Maximum
Dependent variable				
Mean incidence rate of leprosy (per 10 000 inhabitants per year)	1.6	5.4	0.1	14.7
Socioeconomics				
Degree of inequality (Theil's L index)	0.50	0.1	0.2	1.00
Percentage of head of family with monthly income < half the minimum wage	39.5	12.2	9.4	72.2
Education				
Mean years of study among population >25 years	1.9	0.7	0.6	6.1
Percentage of children 7–14 years old that do not go to school	39.9	10.6	17.2	71.1
Sanitation				
Percentage of households with adequate water supply	41.9	22.3	0.6	93.8
Demographics				
Percentage of households with >2 people per room	44.6	8.0	23.9	66.8
Percentage population increase 1991–1996	4.1	10.7	−27.4	93.9
Health				
Infant mortality rate	96.0	22.4	48.8	174.4
No. of physicians per 1000 inhabitants	0.5	0.5	0.00	3.1
No. of public health services per 1000 inhabitants	0.42	0.18	0.07	0.95
Rainfall				
Mean precipitation (mm)	911	253	449	1659

[a] See Methods for details.

Table 2 Person's correlation coefficient among dependent and independent variables

Variables	Incidence of leprosy	Level of inequality	Mean years of study among >25 years	% population growth 1991 to 1996	% children 7 to 14 years old that do not go to school	% households with adequate water supply	Infant mortality rate	Public Health services per 1000 inhabitants	Physicians per 1000 inhabitants	% households with density >2 people per room	Mean rain precipitation 1991 to 1999 (mm)
Incidence rate of leprosy	1.00										
Level of inequality	0.24*	1.00									
Mean years of study among population >25 years old	0.32**	0.26**	1.00								
% population growth 1991–1996	0.16*	−0.12	0.10	1.00							
% children 7–14 years old that do not go to school	−0.09	−0.17*	−0.63	−0.014	1.00						
% households with public water supply	0.13	0.24*	0.35	−0.09	−0.21*	1.00					
Infant mortality rate	0.09	0.03	−0.10	0.13	0.02	−0.15*	1.00				
Public Health services per 1000 inhabitants	0.13	0.14	0.23*	0.20*	−0.28**	0.00	0.10	1.00			
Physicians per 1000 inhabitants	0.32**	0.33**	0.63**	0.19*	−0.40**	0.21*	0.04	0.39**	1.00		
% households with density >2 people per room	0.01	−0.54**	−0.14	0.04	0.15	−0.26**	0.35**	−0.12	−0.04	1.00	
Mean precipitation 1991–1999 (mm)	0.12	0.01	0.32**	0.12	−0.11	−0.12	0.04	0.15	0.26**	0.20*	1.00
% head of family with monthly income ⩽half the minimum wage	−0.14	0.29**	−0.51**	−0.20*	0.26**	−0.01	−0.07	0.03	−0.29**	−0.24*	−0.31**

* significant at 5%, ** significant at 1%.

Table 3 Linear regression model for determinants of incidence of leprosy among 165 municipalities.

Variable	Coefficient β	*P*-value	95% CI
Degree of inequality (Theil's L index)	1.67	0.011	0.389, 2.944
Mean years of study among population 25 years old	1.35	0.000	0.620, 2.081
% population growth 1991–1996	0.02	0.007	0.006, 0.038
% children 7–14 years old that do not go to school	0.02	0.028	0.003, 0.045
Presence of railroad	0.45	0.038	0.025, 0.871
Constant	−3.10	0.000	−4.413, 1.788

$R^2 = 0.20$; F = 8.03; *P*-value < 0.001.

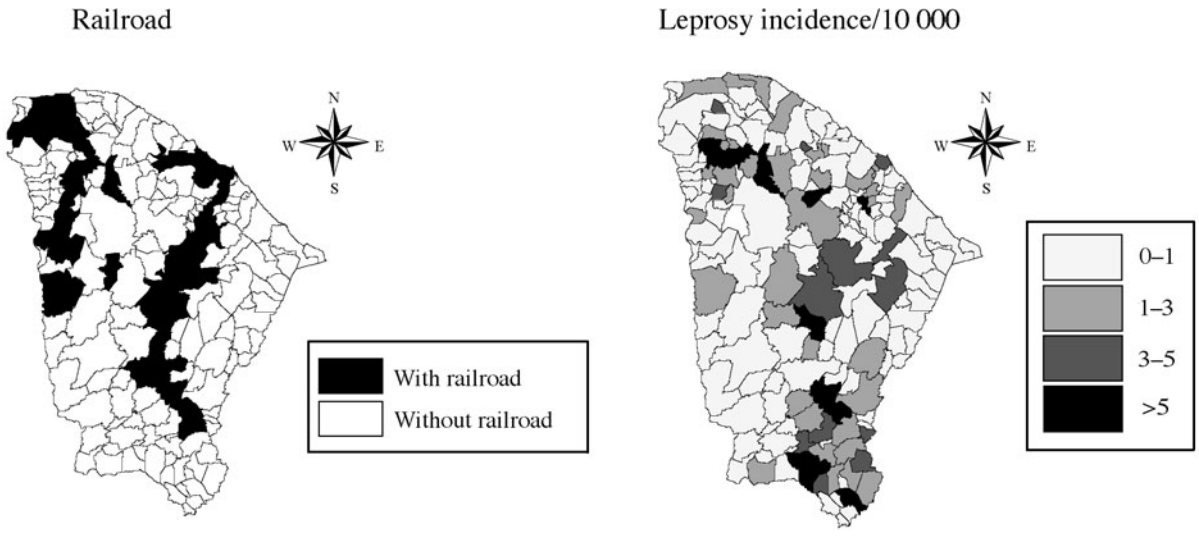

Figure 1 Mean incidence of leprosy in Ceará (1991–1999) and accessibility of municipality by railroad in 1991 or before

control measures, the gap between prevalence and incidence of leprosy has widened between 1991 and 1998.[17] Whereas short-term variations in incidence rates can be easily explained through increasing detection rates e.g. after raising awareness in the population by health education or active case detection during mass surveys,[28] unchanging or even rising incidence rates like those occurring in Ceará over the last decade are difficult to explain without also considering persisting sources of infection with *M. leprae*.[26]

Identifying personal and environmental risk factors for leprosy is extremely difficult. Firstly, in comparison with other infectious diseases, the incubation time is years and not days or weeks. Secondly, the incubation time is different in patients with the polar forms of the disease, i.e. 2–5 years for tuberculoid leprosy and 8–12 years for lepromatous leprosy.[7] Thirdly, in many areas patients are diagnosed only several years after the onset of the disease.[7] Hence, risk factors acting on the individual or at the population level have to be assessed for conditions that existed some 10 to 15 years ago. This implies biases of various sorts.

Taking into account the considerable recall bias if one aims to identify determinants of infection with *M. leprae* at the individual level, the identification of risk factors at the population level appears to be a valid alternative. In order to analyse putative socio-cultural and environmental risk factors we conducted an ecological study in a region characterized by a wide range of incidence rates. Analysing a panel of variables from 165 municipalities we found three types of determinants to be predictors for a high incidence of leprosy, namely socioeconomic inequality, education, and accessibility.

The degree of income inequality, i.e. the degree of inequality in income distribution as measured by the Theil's L index, as well as lack of schooling (indicated by the percentage of school-age children that do not go to school) were significantly associated with the incidence of leprosy. Lack of schooling has been already shown to be risk factor for leprosy at the individual level.[29] Whereas in a cohort study on geographical determinants of leprosy neither socioeconomic nor cultural variables could be identified as risk factors,[16] we showed that, at the population level, the degree of economic inequality is clearly linked to the incidence of leprosy. This means that the more heterogeneous the income distribution in a municipality was, the higher were the odds that leprosy is an important health problem.

The relationship between degree of income inequality and health status in developed countries has been analysed recently.[30,31] The author showed that regions with extreme inequality income tend to have lower health status than regions

with less inequality. In addition, it has been pointed out that relative, but not the absolute, income affects people's health.[32] In fact, inequality rather than wealth seems to be most important determinant for poorer health.[25]

The widely different Theil's L index for the various municipalities of Ceará indicates that economic inequality occurs not only within countries but also within the municipalities of a state. Hence, our finding that inequality within the regions of a state seems to be responsible for different incidence rates confirms what is known from other countries.

Poverty and inequality affect the health of socioeconomically disadvantaged populations in various ways. On one hand, lower social status leads to inadequate housing, lack of hygiene, crowding, and deficient diet; variables that facilitate the spread of many infectious diseases. On the other hand, income inequality has a negative impact on self-esteem, causes stress and unhappiness, and lowers social cohesion, factors that might also negatively affect the health of an individual.[33]

Our finding that the mean years of study among the adult population is positively correlated to a greater incidence rate of leprosy seems to be paradoxical since extended schooling is expected to produce an amelioration of the socioeconomic situation of an individual which, in turn, should lower the incidence of leprosy. However, municipalities with the greatest percentage adult population spending more than 11 years in school could also indicate that these municipalities have a better health infrastructure and therefore have a better capacity to diagnose leprosy. Besides, the proportion of adults with extended schooling can only increase in places where public high schools and/or good private schools are available. As a rule such schools only exist in important urban centres, hence in those municipalities which experienced a great influx of population during the past decade. It is therefore conceivable that the mean duration of schooling is more an indicator of rapid urbanization rather than of education. Furthermore, in the correlation analysis we found that municipalities with mean precipitation rates from 91 to 99 mm presented a smaller number of physicians per 1000 inhabitants. These features could be correlated to each other, e.g. municipalities with little rain are prone to drought and remain economically weak. Hence, they are abandoned by the administrative professionals, including health staff, eventually causing the population to migrate to prospering urban centres looking for better living conditions. Obviously, in municipalities with a lack of qualified health professionals, particularly experienced physicians, the diagnosis of leprosy becomes more difficult.

In fact, in recent decades important population movements have occurred within Ceará. Landless people from the poor hinterland migrated to the state's capital, Fortaleza, and some urban centres of the municipalities experienced a considerable influx of people whereas others lost population.[34] After a great plague and because of lack of appropriate irrigation the population of municipalities that up to the 1950s produced raw materials, especially cotton, decreased dramatically as people moved to other districts where factories were set up which were looking for a labour force.[35] The range of migration within and between municipalities is clearly demonstrated by highly divergent growth rates, e.g. 27.7% to 94.0% in the study period. It is conceivable that the higher the influx of people to the urban area of a municipality the more urbanization proceeded in an uncontrolled way: in municipalities with a high influx more migrants were concentrated on the outskirts of the districts. Such poor neighbourhoods, where people live in substandard social and economic conditions, retained the same characteristics as the rural hinterland e.g bad housing, crowding, lack of sanitation, presence of gardens for horticulture, and keeping of livestock.[12] This, in turn, is expected to increase the number of individuals susceptible to infection with *M. leprae*. It is therefore not unexpected that the relative population increase from 1991 to 1996 was found to be a predictor of the leprosy incidence rate. This contrasts Ceará to areas with little population movement such as Northern Malawi, where the highest prevalence rates of leprosy where observed in the least densely populated areas.[13]

The presence of a railroad in the municipality was also found to be a predictor of leprosy incidence (Figure 1). Although nowadays almost all railways have stopped transporting passengers, until the 1950s, a time when metalled roads were almost non-existent, they were an important means of transport, being cheaper and more reliable than buses. It is obvious that in times when public transportation was only possible by train, towns with railroads experienced a relatively high increase in population as the railroad not only permitted people to move in and out, but also facilitated the export of locally produced merchandise and thereby created jobs. The railroads may also have played a role in spreading leprosy by connecting the different states of the Northeast. Until recently, states such as Pernambuco and Paraíba were severely affected by leprosy. Paraíba had an incidence rate fivefold higher than the overall incidence in Brazil.[21] Thus, not surprisingly, municipalities with access to the railroads frequently overlap municipalities with the greatest leprosy incidence (Figure 1).

Taken together, our findings fit the assumption that in Ceará leprosy is associated with a high level of poverty and rapid, unplanned, and uncontrolled urbanization. We put forward the hypothesis that urbanization increases not only social inequality eventually leading to strong polarization, but also excludes people from social and material opportunities. Such deprivations render them susceptible for various infections, apparently including leprosy. In fact, during an observational study in three municipalities with a high rate of leprosy, the incidence was highest in the municipality with the highest population growth during the last 10 years (H Feldmeier unpublished observation 2002). Moreover, incidence rates in these municipalities were between 2.1 and 5.4 times higher in the urban compared with the rural areas (H Feldmeier unpublished observation 2002).

It is important to remember that the model employed in this study was able to explain only 20% of leprosy incidence in the state of Ceará. It means that person-to-person is still an important mode of transmission and that other as yet unknown factors related to the transmission of leprosy need to be investigated.

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KEY MESSAGES

- Brazil and other developing countries have not achieved the goal of eliminating leprosy.
- A better understanding of the epidemiology of leprosy might help explain why Brazil and other countries are not yet able to decrease leprosy in their populations.
- The more heterogeneous the income distribution in a municipality was, the higher were the odds that leprosy is an important health problem.
- Lack of schooling (indicated by the percentage of school-age children that did not go to school) was significantly associated with the incidence of leprosy.
- Urban crowding may promote the transmission of *Mycobacterium leprae*.
- In Brazil the railroads may also play a role in spreading leprosy by connecting the different states of the Northeast.
- In municipalities with a lack of qualified health professionals, particularly experienced physicians, the diagnosis of leprosy becomes more difficult.

References

[1] Visschedijk J, van de Broek J, Eggens H, Lever P, Beers van S, Klaster P. Review: *Mycobacterium leprae*—millenium resistant! Leprosy control on the threshold of a new era. *Trop Med and Int Health* 2000;**5:**388–99.

[2] Kinnear Brown JA. Factors influencing the transmission of leprosy. *Trans R Soc Trop Med Hyg* 1959;**53:**179–88.

[3] Noordeen SK. The epidemiology of leprosy. In: Hastings RC; Convit J. (eds). *Leprosy*. Edinburgh/London/Melbourne/New York: Churchill Linvingstone, 1985, pp. 15–30.

[4] Levin M, Newport M. Understanding the genetic basis of susceptibility to mycobacterial infection. *Proc Assoc Am Physicians* 1999;**111:**308–12.

[5] Hill AV. The genomics and genetics of human infectious disease susceptibility. *Annu Rev Genomics Hum Genet* 2001;**2:**373–400.

[6] Knight JC, Kwiatkowski D. Inherited variability of tumor necrosis factor production and susceptibility to infectious disease. *Proc Assoc Am Physicians* 1999;**111:**290–98.

[7] Van Beers SM, De Wit MYL, Klatser PR. The epidemiology of *Mycobacterium leprae*: Recent insight. *FEMS Microbiology Letters* 1996; **136:**221–30.

[8] Kazda J. The ecological approach to leprosy: non-cultivable acid-fast bacilli and environmentally-derived *M. leprae*. In: Kazda J (ed.). *The Ecology of Mycobacteriae*. Dordrecht/Boston/London: Kluwer Academic, 2000, pp. 39–46.

[9] Desikan KV, Sreevatsa. Extended studies on the viability of *Mycobacterium leprae* outside the human body. *Lepr Rev* 1995;**66:**287–95.

[10] Matsuoka M, Izumi S, Budiawn T, Nakata N, Saeki K. Mycobacterium leprae DNA in daily using water as a possible source of leprosy infection. *Indian J Lepr* 1999;**71:**61–67.

[11] Van Beers SM, Hatta M, Klatser PR. Patient contact is the major determinant in incident leprosy: implications for future control. *Int J Lepr Other Mycobact Dis* 1999;**67:**119–28.

[12] Fine PE, Sterne JA, Ponnighaus JM *et al.* Household and dwelling contact as a risk factors for leprosy in northern Malawi. *Am J Epidemiol* 1997;**146:**91–102.

[13] MILEP2 Sudy Group. Aproaches to studying the transmission of *Mycobacterium leprae*. *Lepr Rev* 2000;**71(Suppl.):**S26–29.

[14] Lechat MF. The source of infection: an unsolved problem. *Indian J Lepr* 2000;**72:**1–5.

[15] Mani MZ. Ecological factors in transmission of leprosy. *Indian J Lepr* 1996;**68:**375–77.

[16] Sterne JAC, Ponnighaus JM, Fine PEM, Malema S. Geographic determinants of leprosy in Karonga District, Northern Malawi. *Int J Epidemiol* 1995;**24:**1211–22.

[17] SESA—CE (Secretaria de Saúde do Estado do Ceará). *Situação Epidemiológica e Operacional da Hanseníase, Ceará, 1998, Fortaleza*. 1999.

[18] SESA—CE (Secretaria de Saúde do Estado do Ceará). *Hanseníase: Situação Epidemiológica e Operacional em 1999, Fortaleza*. 2000.

[19] Tavares CM. *Evolução da Endemia Hansênica no Estado do Ceará. Características Epidemiológicas e Operacionais no Período de 1970 a 1996. Universidade Federal do Ceará 1997*. Tese de Mestrado.

[20] IBGE (Instituto Brasileiro de Geografia e Estatística). Censo Demográfico 1991. 4 October 2001. http://www.ibge.gov.br.

[21] IPLANCE (Instituto de Planejamento do Estado do Ceará), *Indicadores Sociais dos Municípios do Ceará*. Censo demográfico 1991/IBGE. Fascículos 1–4. Fortaleza, Ceará. 1995.

[22] IPEA (Instituto de Pesquisa Econômica e Aplicada). *Atlas de Desenvolvimento Humano no Brasil*. 1998.

[23] SESA—CE (Secretaria de Saúde do Estado do Ceará). *Boletim Epidemiológico e operacional da Hanseníase*. 2002.

[24] Figueiredo IA, Silva AAM. Increase in leprosy detection rates in São Luís, Maranhão, Brazil, from 1993 to 1998. Is the endemic expanding? *Cad Saúde Publica* 2003;**19:**439–45.

[25] Martelli CMT, Stefani MMA, Penna GO, Andrade ALSS. Brazilian endemisms and epidemics, challenges and prospects for scientific investigation: leprosy. *Rev Bras Epidemiol* 2002;**5:**273–85.

[26] Cunha SS, Rodrigues LC, Moreira S, Carvalho LC, Barreto M, Dourado I. Upward trend in the rate of detection of new cases of leprosy in the state of Bahia, Brazil. *Int J Lepr* 2001;**69:**308–17.

[27] FUNASA (Fundação Nacional de Saúde). *Boletim Epidemiológico* 1999; Edição Especial.

[28] Chen XS, Li WZ, Jiang C, Ye GY. Leprosy in China: epidemiological trends between 1949 and 1998. *Bull World Health Organ* 2001;**79:**306–12.

[29] Ponnighaus JM, Fine PEM, Sterne JAC *et al*. Extended schooling and housing conditions are associated with reduced risk of leprosy in rural Malawi. *Int J Lepr* 1994;**62:**345–52.

[30] Coburn D. Income inequality, social cohesion and the health status of populations: the role of neo-liberalism. *Soc Sci Med* 2000;**51:** 135–46.

[31] Fiscella K, Franks P. Individual income, income inequality, health, and mortality: What are the relationships? *Health Serv Res* 2000;**35:**307–18.

[32] Wilkinson RG. Low relative income affects mortality. *BMJ* 1998; **316:**1611.

[33] Wilkinson RG. Socioeconomic determinants of health: health inequalities: relative or absolute material standards? *BMJ* 1997;**314:**591.

[34] IBGE (Instituto Brasileiro de Geografia e Estatística). *Censo Demográfico 2000*. 12 November 2002. http://www.ibge.gov.br.

[35] Ferreira A. O crescimento recente da economia Cearense. *R Econ Nord* 1995;**26:**157–80.

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Commentary: Leprosy and poverty

Diana NJ Lockwood

A hundred years ago the hot debate in leprosy circles revolved around disease causation; was leprosy hereditary or could the bacterial hypothesis of Armauer Hansen be believed? These arguments had important and very different public health consequences. If hereditary then patients should be stopped from reproducing but did not need isolation and confinement. However, if a bacterial aetiology was believed then leprosy patients should be isolated from society to prevent spread of infectious organisms. At that time there were no effective antibiotics for treating leprosy.

We still have an imperfect understanding of the transmission and causation of leprosy and the importance of various factors in disease causation still influence public health policy. The study in this issue of the *International Journal of Epidemiology* by Kerr-Pontes *et al*.[1] showing an association between poverty and leprosy is an important new contribution to today's debate. Leprosy is caused by *Mycobacterium leprae* and has a long incubation period, ranging from 5 to 15 years.[2] Patients with lepromatous leprosy shed mycobacteria in their nasal secretions thereby continuing infection. *M. leprae* is a hardy organism and can survive for up to 5 months in India.[3] Molecular techniques have shown that in endemic areas up to 5% of the population are carrying *M. leprae* DNA in their noses.[4] Leprosy has an uneven geographical spread; 85% of the world's patients live in six countries (India, Brazil, Nepal, Myanmar, Mozambique, and Madagascar).[5] Even in low endemic countries such as South Africa certain regions are identified with new leprosy cases.

Some risk factors have been identified for leprosy; household contact with a lepromatous patient is an important risk factor, but only 20–30% patients have a recognizable contact with a known patient with leprosy. Recent studies in India and Brazil have shown a linkage between particular genotypes and the risk of developing of paucibacillary leprosy.[6] BCG vaccination has a consistent, but variable, protective effect against leprosy.[7]

A link between leprosy and poverty has long been suspected, but is difficult to demonstrate at national, community, or even individual levels. There are no clear correlations between national GDP levels and leprosy new case detection rates. Some countries with very low scores on the human development index such as Burkina Faso and Benin (rated 155 and 169, respectively) have low new case detection rates, whereas Brasil (rated 63rd) has the second highest new case detection rate.[8] At an individual-level, a study done in Malawi showed that living in a crowded household was a risk factor, as was lack of schooling.[9]

The Kerr-Pontes study shows at a community level in a high endemic area of leprosy in Brasil the level of inequality, population growth, and presence of a railroad are associated with higher levels of leprosy. Their study is particularly valuable in that they have looked at data over 9 years and so can account for the long incubation period. Population growth and inequality may cause over-crowding so facilitating aerosol transmission of *M. leprae*. It is particularly interesting that the level of inequality rather than absolute poverty should be correlated with leprosy case rates. Wilkinson has argued that inequalities produce unmet social needs and so impair health. Leprosy should perhaps be seen as an affliction of an unhealthy society.[10] This is an interesting new twist for a disease that has long been associated with blame being put on the individual who is then stigmatized.

Big questions currently hang over the public health approaches to leprosy control. Despite having effective antibiotic

London School of Hygiene and Tropical Medicine, Keppel St, London, WC1E 7HT, UK. E-mail: diana.lockwood@lshtm.ac.uk