Zip Code–Level Risk Factors for Tuberculosis: Neighborhood Environment and Residential Segregation in New Jersey, 1985–1992

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A B S T R A C T

Objectives. This study examined zip code–level risk factors associated with very high tuberculosis (TB) rates among non-Hispanic Whites, African Americans, Hispanics, and Asians in New Jersey (1985–1992).

Methods. Exposure indices (poverty, crowded housing, and dilapidated housing) and segregation indices (contact with immigrants, isolation, and density) were used to characterize zip codes. A Boolean-logic methodology was used to determine which configurations of risk factors significantly distinguish zip codes where TB rates are very high from other zip codes.

Results. For Whites and Asians, risk factors were rare in zip codes with very high TB rates. In agreement with the distribution of TB cases by age and foreign-born status, this suggests that cases among Whites may be caused by reactivation, whereas cases among Asians may be imported. In contrast, Hispanics and African Americans were exposed to risk factors that may facilitate TB transmission. Among Hispanics, high contact with immigrants was an important factor. African Americans were the group most frequently exposed to multiple risk factors.

Conclusions. For Hispanics and African Americans, zip code–level risk factors were associated with very high TB rates. (*Am J Public Health.* 2001;91: 734–741)

In this article, I examine zip code–level risk factors associated with very high tuberculosis (TB) rates among Whites (non-Hispanic Whites), African Americans (non-Hispanic Blacks), Hispanics, and Asians in New Jersey from 1985 to 1992, a period when TB was on the rise in the United States. In 1990, New Jersey was the state with the ninth highest TB rate; Newark had the highest TB rate among cities with populations of 250 000 or more; and Paterson, Jersey City, and Elizabeth had the 2nd, 8th, and 11th highest TB rates, respectively, among cities with populations of 100 000 to 250 000.[1] As in the rest of the United States, in New Jersey TB is geographically concentrated in urban areas (Figure 1) and disproportionately affects racial/ethnic minorities.[2]

Despite the observation that TB historically has been associated with environmental etiologies,[3–5] with some exceptions[6] little attention has been given to the role of environmental factors in explaining the disproportionately high TB incidence among US minorities.[7]

Individual-level factors (e.g., a history of alcoholism or HIV infection) may make an individual more susceptible to TB. However, the differential prevalence of this disease among various population subgroups can be better explained by the quality of the physical (e.g., crowded and dilapidated housing) and social (e.g., poverty concentration) environment inhabited by these subgroups.[8] Additionally, the contact and density patterns of various population subgroups are key determinants of the heterogeneity in infectious disease transmission.[9–11] As suggested recently in this Journal,[12] infectious disease levels in populations can be influenced more by population patterns of exposure than by the exposure status of individuals.

Both the quality of the social and physical environment and the contact and density patterns are the outcome of socially patterned processes, such as residential segregation, and, therefore, are unequally distributed along racial/ethnic lines. For instance, African Americans are more likely to live in concentrated-poverty neighborhoods and to be residentially isolated than are other groups.[13,14]

Methods

Data

TB cases by race/ethnicity from 1985 to 1992 were obtained from the Division of Communicable Diseases, New Jersey Department of Health. The data contain clinical and demographic information and the zip code of residence for 6696 TB cases. Geographic Information Systems software (Atlas GIS 3.0; Strategic Mapping, Inc, Santa Clara, Calif) was used to match the zip code of residence with 1990 census demographic and socioeconomic information at the block group level, which allowed the construction of exposure and segregation indices. We calculated average annual TB rates at the zip code level for each racial/ethnic group by using the total number of cases for the racial/ethnic group of interest as the numerator and the 1990 population of the respective racial/ethnic group as the denominator.

We grouped analytic variables into 5 domains: poverty, crowding, dilapidation, immigration, and segregation. Considerable historical and contemporary evidence indicates that TB is positively associated with low socioeconomic status (e.g., poverty)[5,6,8,15–17] and substandard housing conditions (e.g., crowding and dilapidation).[18–20] Residential segregation may have an *indirect effect* on TB trans-

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mission through the quality of the physical and social environment (i.e., segregation may result in poverty concentration, overcrowding, and housing dilapidation).[21]

Segregation also may have a *direct effect* on TB transmission by shaping contact patterns between infectious and susceptible individuals and the density of susceptible individuals.[21] Two dimensions of residential segregation—isolation and concentration[22,23]—have immediate epidemiologic significance. Limited contact with the rest of the population may reduce the probability of transmission between the segregated group and the rest of the population. Additionally, if an isolated group experiences high concentration (i.e., high population densities), the probability of transmission within this group may be higher.[21]

Furthermore, the high TB incidence among US minorities may be partially due to the presence of infected immigrants from high-prevalence countries and to transmission from these immigrants to the native born.[21,24]

Finally, interaction patterns between populations in different areas affect the persistence of an infectious agent in the space occupied by the total population.[10,11] However, because of insufficient data, this study did not examine these effects.

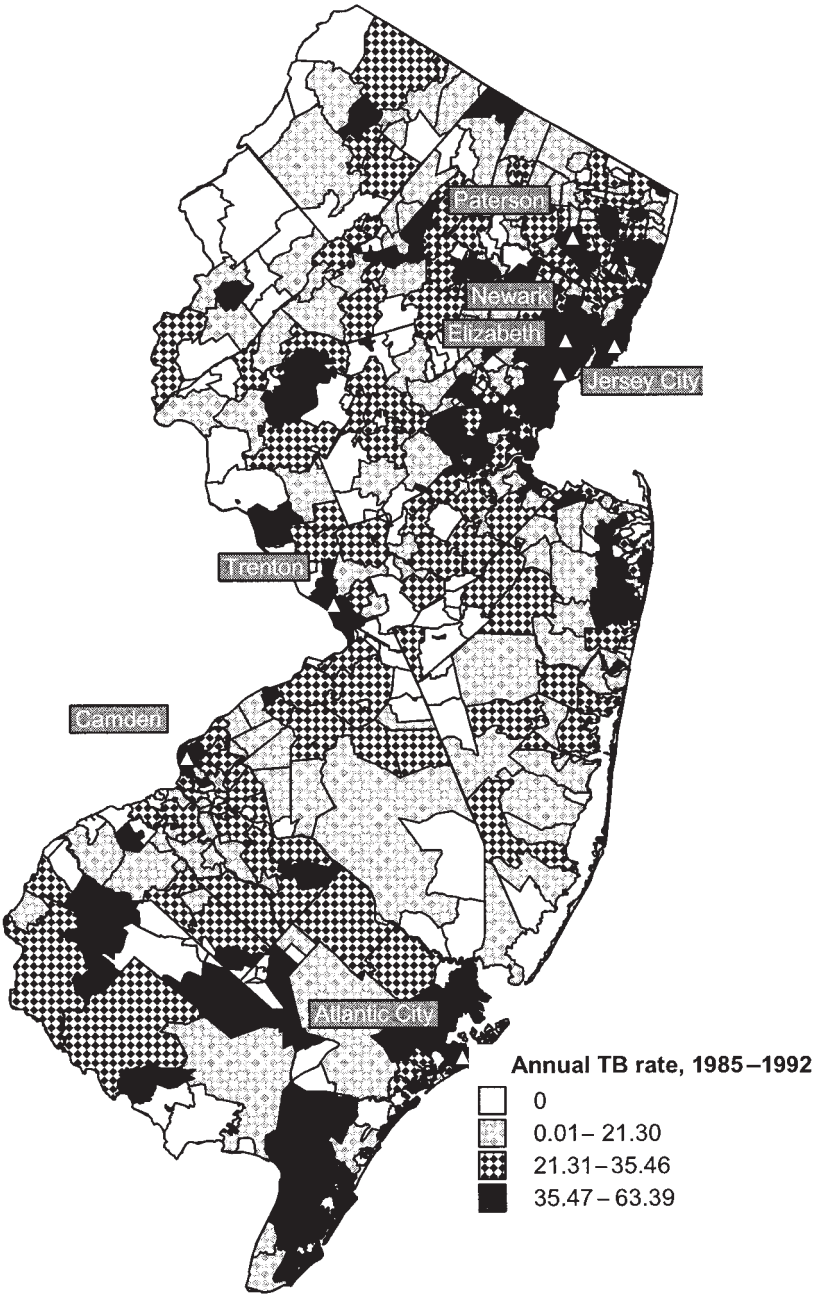
Exposure Indices

By definition, the calculation of exposure, isolation, contact with immigrants, and density indices requires 2 geographic scales. Exposure to a given social condition is measured for a given geographic area by looking at the *distribution* of this social condition and the racial/ethnic group of interest across smaller geographic subunits within that area. Exposure indices capture the quality of block-group environment in a given zip code as experienced by the average member of a given racial/ethnic group. The formula for the exposure indices is similar to the formula for the isolation index used in the segregation literature[14,22,23] (also D. Massey, PhD, S. Kanaiaupuni, PhD, unpublished data, 1992).

The exposure-to-poverty index has been used to examine the relation of residential segregation to poverty concentration (i.e., the distribution of poverty across neighborhoods in a given metropolitan area).[13,14] Similarly, the exposure indices used here refer to the distribution of risk factors (i.e., poverty, crowded and dilapidated housing) across block groups in a given zip code. Because we were interested in residential segregation patterns, aggregate risk factor measures at the zip code level, such as the overall zip code poverty rate, would not have been appropriate. Conceptually, residential segregation is linked to the distribution of risk factors across subunits of a given area and to the average prevalence of risk factors in those subunits.[21,25] Therefore, we used exposure indices.

For each zip code (j) and each racial/ethnic group (m), indices of exposure to poverty (EP^{jm}) and overcrowded (EC^{jm}) and dilapidated (ED^{jm}) housing were calculated. These indices are defined as

$$EP^{jm} = \sum_{i=1}^{N} \frac{x_i^{jm}}{X^{jm}} \frac{e_i^j}{t_i^j}$$



Note. First quartile includes 160 zip codes with no TB cases, second quartile includes 137 zip codes, and third and fourth quartiles include 147 zip codes each. The total TB rate is the total number of new TB cases in 1985–1992 divided by the 1990 total population.

FIGURE 1—Average annual total tuberculosis (TB) rate (per 100 000): New Jersey zip codes, 1985–1992.

$$EC^{jm} = \sum_{i=1}^{N} \frac{x_i^{jm}}{X^{jm}} \frac{c_i^j}{h_i^j}$$

$$ED^{jm} = \sum_{i=1}^{N} \frac{x_i^{jm}}{X^{jm}} \frac{d_i^j}{h_i^j}$$

where x_i^{jm}, t_i^j, and X^{jm} are, respectively, the number of members of the group *m* in block group *i,* the total population of block group *i,* and the number of members of the minority group *m* for the entire zip code *j;* e_i^j, d_i^j, c_i^j, and h_i^j are, respectively, the number of persons living in poverty, the number of rented (as opposed to owned) housing units, the number of overcrowded housing units, and the total number of housing units in block group *i*; *N* is the total number of block groups in zip code *j*. To illustrate with an example: EP^{jm}=0.15 indicates that in zip code *j*, the typical member of group *m* lives in a block group where 15% of the population lives in poverty.

Segregation Indices

Recently, infectious epidemiology theorists have emphasized the importance of developing methods to study the contact patterns of populations.[9,11,12] Social network data can be gathered from a sample of individuals about their contacts.[26,27] Alternatively, overall population contact patterns can be described by segregation indices.

Residential segregation has 5 dimensions: unevenness, isolation, concentration, clustering, and centralization.[22,23] As discussed earlier, isolation and concentration have epidemiologic significance for the study of TB. The isolation index, which measures the extent to which a member of a racial/ethnic group (*m*) is likely to be in contact with members of this same group (as opposed to members of other groups), is given by[22,28]

$$P^{jm} = \sum_{i=1}^{N} \frac{x_i^{jm}}{X^{jm}} \frac{x_i^{jm}}{t_i^j}$$

where all the variables were defined previously; e.g., P^{jm}=0.6 indicates that in zip code *j*, the average member of group *m* lives in a block group where the probability that he or she will have contact with another member of group *m* is 0.6.

Similarly, the index of contact with immigrants is defined as

$$CI^{jm} = \sum_{i=1}^{N} \frac{x_i^{jm}}{X^{jm}} \frac{i_i^j}{t_i^j}$$

where i_i^j is the number of foreign-born people in block group *i*; CI^{jm} may be interpreted as the probability that in zip code *j*, the average member of group *m* will have contact with immigrants in his or her block group.

Finally, concentration is defined as the average density experienced by a racial/ethnic group. We differentiate between the density of members of a particular racial/ethnic group and the density of members of all racial/ethnic groups and refer to these 2 facets of density as *partial density* and *total density,* respectively. Partial density is a proxy for the probability of contact within a particular racial/ethnic group, whereas total density is a proxy for the probability of contact among members of various racial/ethnic groups.

The partial density measure (PD^{jm}) gives the number of persons of racial/ethnic group *m* per square kilometer (at the block group level) encountered by the average member of that group living in zip code *j*:

$$PD^{jm} = \sum_{i=1}^{N} \frac{x_i^{jm}}{X^{jm}} \frac{x_i^{jm}}{a_i^j}$$

where a_i^j is the total area of block group *i* (in km^2) within zip code *j*. Thus, PD^{jm}=2500 indicates that in zip code *j*, the average member of group *m* inhabits a block group where there are 2500 members of that group per square kilometer.

Boolean Analytic Methodology

We analyzed the data with a Boolean methodology. Boolean methods have been used in political science and sociology[29,30] and more recently in health research to study mental health outcomes (i.e., depression)[31–33] and child development outcomes.[34] Applications to health services research also have been suggested (C.C. Ragin, PhD, unpublished data, 1999). The methodology used in this article follows that proposed by Singer et al.,[33] who used it to examine health survey data from the Wisconsin Longitudinal Study.

The key distinction between regression analyses and Boolean analyses is that the former are appropriate for answering variable-oriented research questions, whereas the latter are appropriate for answering case-oriented research questions[33] (also C.C. Ragin, PhD, unpublished data, 1999). Consider a data matrix in which columns correspond to variables and rows correspond to cases. Regression analyses focus on the columns—that is, on the average effect of a given variable on the outcome variable across all cases (holding the rest of the analytic variables constant). Boolean analyses focus on the rows—that is, on the combinations of analytic variables that characterize cases that share a common outcome[33] (also C.C. Ragin, PhD, unpublished data, 1999).

Thus, regression and Boolean methodologies do not contradict one another, but simply best answer different research questions. As Ragin suggested, exaggerating the contrasts between variable-oriented and case-oriented methods contributes to their reification and to the perception that the 2 approaches cannot be reconciled (C.C. Ragin, PhD, unpublished data, 1999). In this study, the research questions were (1) What are the most common risk factors in each zip code with very high TB rates for various racial/ethnic groups? and (2) What are the similarities and differences in risk factors among zip codes with very high TB rates across various racial/ethnic groups? A case-oriented methodology was appropriate because we were not interested in assessing the (average) effect of risk factors on TB rates but in describing various configurations of risk factors found in actual zip codes characterized by very high TB incidence.

It is important to clarify that the distinction between regression and Boolean analyses does not lie in the type of data used (i.e., health survey and surveillance data can be analyzed with both methods), the level of analysis (i.e., individual-level and ecologic analyses can be performed with both methods), or the use of categoric variables (which may be used in both regression and Boolean methods).

The essential methodological steps in the present Boolean analysis are described below.

Classification of zip codes in 4 groups. For each racial/ethnic group, zip codes were divided into no TB (i.e., those zip codes with no TB cases), low TB (i.e., those zip codes in the first tercile by TB rate among those zip codes with TB cases), high TB (i.e., those zip codes in the second tercile by TB rate), and very high TB (i.e., those zip codes in the third tercile by TB rate).

Selection of threshold values to translate continuous variables into dichotomous variables. Epidemiologic information on contemporary US environmental factors associated with TB incidence is limited. Therefore, stringent criteria were used to construct profiles of zip code–level risk factors that may be conducive to TB transmission.

Poverty. High exposure to poverty was defined as poverty rates of 20% or greater, to avoid focusing on areas characterized as ghettos, which have been found to be associated with poverty rates of 40% or greater.[13,35] In contrast, poverty rates in the 20% to 40% range include working-class and lower-middle-class neighborhoods.[13]

Crowding. In 1990, the proportion of crowded housing units (≥1.0 persons per room) was about 4.9% nationwide and 3.9% in New Jersey. Among the largest metropolitan areas, only Los Angeles, Calif, had an overcrowding rate of more than 10%.[36] This value was used as a threshold for defining high exposure to crowded housing.

Dilapidation. The proportion of rented (vs owned) housing was used as a proxy for dilapidation. According to the American Hous-

ing Survey, rental units are more likely to be structurally inadequate than are owner-occupied units.[37] In 1990, the overall New Jersey home-ownership rate was 65%, but only 35% for African Americans and Hispanics. The minority rented housing rate (65%) was used to define high exposure to dilapidation.

Immigration. In 1990, 12.5% of the population and 20.5% of the persons with TB in New Jersey[1] were foreign born. The latter (more stringent) figure was used to define high contact with immigrants.

Isolation. The accepted definition of high isolation in the demographic and sociologic literature ($P^{jm} \geq 0.60$) was used to define high isolation.[14]

Concentration. The average density in the 4 New Jersey cities with the highest TB rates in 1990 (i.e., Newark, Paterson, Jersey City, and Elizabeth)[38] was used to define high partial density ($PD^{jm} \geq 5100$ persons/km^2). Given that partial density refers to the density of persons of a specific racial/ethnic group, this is a strict definition of partial density.

Selection of simple and complex Boolean statements to characterize zip code–level risk factors conducive to TB transmission. A Boolean-logic methodology requires dichotomous variables. Each of these variables can be thought of as the truth value of a simple Boolean statement about a zip code. For instance, consider the statement $EP^{jm} \geq 0.20$. If the statement is true (i.e., if $EP^{jm} \geq 0.20$), the corresponding variable is 1; if the statement is not true (i.e., if $EP^{jm} < 0.20$), the corresponding variable is 0. The next step is to construct complex Boolean statements that incorporate several simple statements. These complex statements can be interpreted as configurations of risk factors for TB transmission at the zip code level (e.g., $EP^{jm} \geq 0.20$ AND $EC^{jm} \geq 0.10$). Hereafter, we use "^" to denote the Boolean operator "AND."

Identification of the most common configurations of risk factors associated with zip codes with very high TB rates. For a combination of m simple Boolean statements, the number of logically possible configurations is 2^m. For each racial/ethnic group, we determined the most frequent complex Boolean statements (configurations of exposure to risk factors and segregation dimensions) among zip codes with very high TB rates by constructing truth tables[30] (also C.C. Ragin, PhD, unpublished data, 1999). Truth tables show all the possible configurations for a set of variables. The construction of truth tables allows one to rank all the logically possible configurations according to their actual frequency in the data (i.e., it provides a picture of the diversity of the data). Here, the most frequent configurations were defined as those that cover at least 10% of the zip codes, starting with the most frequent configuration followed by the next frequent one until 50% of the zip codes were covered. The software QCA 3.0[39] was used to construct the truth tables.

Determining whether the most frequent configurations statistically distinguish zip codes with very high TB rates from the other 3 types. The most frequent configurations among zip codes with very high TB rates were used as differentiation hypotheses. We calculated the proportion of zip codes within each group that fulfilled a given Boolean statement and tested whether the relevant proportion was statistically significantly different between zip codes with very high TB rates and the remainder. We used a 1-sided z test of the difference in proportions.[40,41] Because multiple comparisons (i.e., comparisons between zip codes with very high TB rates and each of the other 3 types of zip codes) were involved, the Bonferroni adjustment, $? = P/n$, was applied.[42,43] P is the desired significance level (i.e., .5), n is the number of comparisons, and $?$ is the (more strict) significance level to be applied. Here, $P = .05$, $n = 3$, and $? = .017$.

Results

In 1985 through 1992, 27% of the TB cases in New Jersey occurred among non-Hispanic Whites, 50% occurred among African Americans, 15% occurred among Hispanics, and 8% occurred among Asians. African Americans had the highest average annual TB rate, followed by Asians, Hispanics, and Whites (Table 1). Among zip codes with very high TB rates, the average annual TB incidence rate was considerably higher for African Americans than for the other racial/ethnic groups. In addition, African Americans were the most frequently exposed to an environment where TB incidence was very high (i.e., about 31% of the Whites, 29% of the Hispanics, and 26% of the Asians lived in zip codes with very high TB rates, compared with nearly 50% of the African Americans; Table 1).

Descriptive Statistics

For each racial/ethnic group and each type of zip code, Table 2 shows the mean values of the annual TB incidence rate and exposure and segregation indices.

In agreement with the only previous zip code–level study of TB among US minorities,[6] we generally found an increase in exposure to risk factors, contact with immigrants, isolation, and density as we moved from no TB to very high TB zip codes. However, these gradients varied by racial/ethnic group. Figure 2 presents 2 examples. Although there is a positive gradient in exposure to crowded housing for all groups, the mean level of exposure to crowding is considerably higher for African Americans and Hispanics in low, high, and very high TB zip codes (panel A). There is a negative isolation gradient for Whites, a positive one for African Americans and Hispanics, and no gradient for Asians (panel B).

Prevalence of Single Ecologic Risk Factors

Table 3 includes simple (i.e., single variable) and complex Boolean statements across no, low, high, and very high TB zip codes.

Whites. For Whites, single risk factors were more common in zip codes with very high TB rates, ranging from 6% for high exposure to poverty to 32% for high contact with immigrants. High White isolation was the norm in all types of zip codes. However, it was less common in zip codes with very high TB rates. High density levels among Whites were rare, even in zip codes with very high TB rates.

African Americans. African Americans in zip codes with very high TB rates were sharply distinct from those in the other zip codes. The frequency of single risk factors (ranging from 31% for high contact with immigrants to 69% for high exposure to dilapidation) in these zip codes was considerably higher than that in each of the other types of zip codes and much higher than that for Whites. African American isolation and density also were more common in zip codes with very high TB rates.

Hispanics. For Hispanics, exposure to poverty, crowding, dilapidation, and immigrants was higher in zip codes with very high TB rates than in each of the other 3 types. High Hispanic isolation and partial density were rare and did not distinguish zip codes with very high TB rates.

Asians. For Asians, exposure to poverty, crowding, dilapidation, and immigrants was higher in zip codes with very high TB rates than in each of the other 3 types, but, in general, these risk factors were lower than those for African Americans and Hispanics. Asians did not experience high isolation or high partial density in any type of zip code.

Configurations of Risk Factors Associated With Very High TB Rates

For each racial/ethnic group, we analyzed 2 classes of complex Boolean statements. Class 1 (which represents the *indirect effects* of residential segregation on TB transmission through the quality of the physical and social environment) included the 8 possible configurations of 3 risk factors: high exposure to poverty, crowded housing, and dilapidated housing.

TABLE 1—Tuberculosis (TB) Cases and Rates, by Race/Ethnicity, Type of Zip Code, Age (<65 Years), and Nativity: New Jersey, 1985–1992

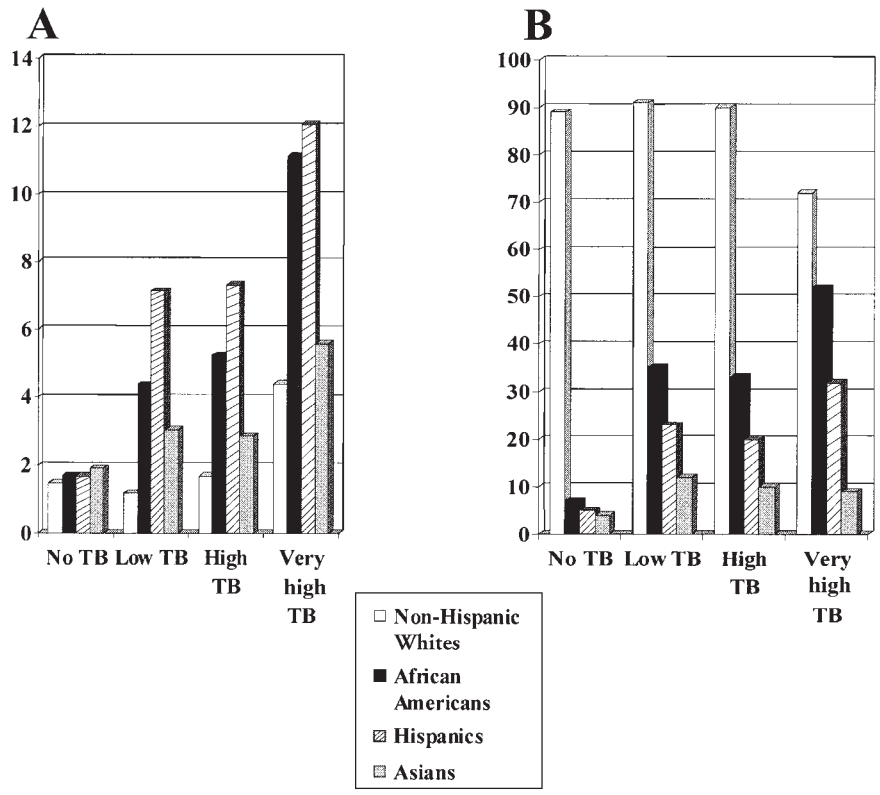
	No. of Zip Codes	Annual Mean TB Rate	No. of TB Cases	% Total TB Cases	Population	% Total Population	% Cases Aged < 65 y	% Foreign-Born Cases
Non-Hispanic Whites								
No TB	149	0.00	0	0.00	713 297	13.43	0.00	0.00
Low TB	99	1.40	171	11.49	1 530 155	28.81	53.22	7.02
High TB	99	2.77	310	20.83	1 400 409	26.36	54.19	6.77
Very high TB	100	7.55	1007	67.67	1 668 175	31.40	63.16	14.40
Total	447	3.50	1488	100.00	5 312 036	100.00	60.15	11.96
African Americans								
No TB	318	0.00	0	0.00	81 806	8.50	0.00	0.00
Low TB	45	8.84	128	4.57	181 081	18.82	80.47	7.81
High TB	45	20.64	362	12.92	219 205	22.78	83.43	8.29
Very high TB	45	60.16	2311	82.51	480 169	49.90	91.65	6.62
Total	453	36.39	2801	100.00	962 261	100.00	90.07	6.89
Hispanics								
No TB	373	0.00	0	0.00	131 842	17.49	0.00	0.00
Low TB	35	9.66	198	23.52	256 136	33.98	89.39	70.20
High TB	34	16.36	194	23.04	148 270	19.67	92.78	56.19
Very high TB	34	25.87	450	53.44	217 459	28.85	93.33	58.67
Total	476	13.96	842	100.00	753 707	100.00	92.28	60.81
Asians								
No TB	281	0.00	0	0.00	56 554	24.07	0.00	0.00
Low TB	42	14.35	66	14.90	57 484	24.47	81.82	77.27
High TB	42	25.91	123	27.77	59 330	25.26	82.11	85.37
Very high TB	42	51.59	254	57.34	61 541	26.20	90.55	87.01
Total	407	23.57	443	100.00	234 909	100.00	86.91	85.10

Note. Zip codes with no population for the group of interest were not included in the respective analysis. Zip codes with a TB rate higher than the median rate (after exclusion of those zip codes with no TB cases for the group of interest) *and* those with fewer than 5 TB cases were not included in the analysis. For each racial/ethnic group, the *annual mean TB rate* is the weighted-average TB incidence rate (per 100 000) among zip codes in the group of interest. The TB rate is the total number of new TB cases for the racial/ethnic group of interest during the study period (1985–1992) divided by the 1990 population for the racial/ethnic group of interest. The weight used was the 1990 population of the respective racial/ethnic group.

TABLE 2—Mean Values of Outcome and Analytic Variables, by Race/Ethnicity and Type of Zip Code: New Jersey, 1985–1992

	TB Rate (per 100 000)	Exposure to Poverty	Exposure to Crowded Housing	Exposure to Dilapidated Housing	Contact With Immigrants	Residential Isolation	Partial Density, Persons/km^2
Non-Hispanic Whites							
No TB	0.00	4.23	1.49	18.58	6.85	89.00	750
Low TB	1.40	3.58	1.18	20.12	8.16	91.00	1220
High TB	2.77	4.38	1.70	24.07	8.71	90.00	1420
Very high TB	7.55	8.43	4.39	39.80	16.68	72.00	2800
African Americans							
No TB	0.00	4.63	1.69	25.76	8.33	7.00	100
Low TB	8.84	10.22	4.38	36.52	7.31	35.00	870
High TB	20.64	10.55	5.23	43.49	12.06	33.00	1470
Very high TB	60.16	21.53	11.13	66.71	16.23	52.00	4800
Hispanics							
No TB	0.00	4.47	1.69	23.32	8.10	5.00	100
Low TB	9.66	12.84	7.12	46.73	19.00	23.00	1860
High TB	16.36	11.43	7.31	46.85	18.15	20.00	1700
Very high TB	25.87	17.83	12.06	65.49	25.36	32.00	2680
Asians							
No TB	0.00	4.80	1.92	24.22	8.26	4.00	70
Low TB	14.35	4.16	3.04	30.41	20.20	12.00	410
High TB	25.91	5.27	2.85	29.34	17.04	10.00	310
Very high TB	51.59	8.44	5.59	42.20	20.73	9.00	510

Note. TB = tuberculosis. Zip codes with no population for the group of interest were not included in the respective analysis. Zip codes with a TB rate higher than the median rate (after exclusion of those zip codes with no TB cases for the group of interest) *and* those with fewer than 5 TB cases were not included in the analysis. For each racial/ethnic group, the TB rate is the annual mean TB rate (i.e., the weighted-average TB incidence rate per 100 000 among zip codes in the group of interest). The TB rate is the total number of new TB cases for the racial/ethnic group of interest during the study period (1985–1992) divided by the 1990 population for the racial/ethnic group of interest. The weight used was the 1990 population of the respective racial/ethnic group for each zip code.



Note. TB = tuberculosis.

FIGURE 2—Mean exposure to crowding (A) and isolation (B), by racial/ethnic group and type of zip code.

Class 2 (which represents the *direct effects* of segregation on TB transmission through contact patterns between infectious and susceptible individuals and the density of susceptible individuals) included the 64 possible configurations combining the 3 risk factors plus high exposure to immigrants, high isolation, and high partial density (Table 3). In the following paragraphs, we discuss the most frequent configurations (as defined earlier) for each racial/ethnic group and whether they significantly distinguished zip codes with very high TB rates from the rest.

Whites. Class 1. In the majority (80%) of the zip codes with very high TB rates, there were no apparent risk factors for TB transmission (denoted as 0^0^0). However, the absence of risk factors was significantly less common in zip codes with very high TB rates than in the other 3 types.

Class 2. In nearly 60% of the zip codes with very high TB rates, Whites lived in high isolation from other groups, but other risk factors were absent (0^0^0^0^1^0). High White isolation was less frequent in zip codes with very high TB rates than in the other 3 types.

African Americans. Class 1. A combination of high exposure to poverty and overcrowded and dilapidated housing was significantly more prevalent in zip codes with very high TB rates (1^1^1); in 42% of these zip codes, the average African American lived in a block group where at least 20% of the population lived in poverty, at least 10% of the housing units were overcrowded, and at least 65% of the housing units may have been dilapidated. Although in 20% of the zip codes with very high TB rates, this combination of risk factors was not present (0^0^0), the absence of risk factors was significantly more common in the other 3 types of zip codes.

Class 2. The 3 most frequent configurations were (1) high exposure to poverty and overcrowded and dilapidated housing and high contact with immigrants but no high isolation or high partial density (1^1^1^1^0^0); (2) high exposure to poverty and overcrowded and dilapidated housing but no high contact with immigrants, high isolation, or high partial density (1^1^1^0^1^1); and (3) absence of risk factors for TB transmission (0^0^0^0^0^0).

Hispanics. Class 1. For Hispanics, a combination of high exposure to poverty and overcrowded and dilapidated housing (1^1^1) was the most common configuration in zip codes with very high TB rates. Two other common configurations were (1) the absence of these 3 risk factors (0^0^0) and (2) low exposure to poverty plus high exposure to overcrowded and dilapidated housing (0^1^1).

Class 2. The 4 most frequent configurations were (1) high contact with immigrants in the absence of other risk factors (0^0^0^1^0^0); (2) high exposure to overcrowded and dilapidated housing and high contact with immigrants in the absence of the other risk factors (0^1^1^1^0^0); (3) high exposure to poverty, high exposure to overcrowded and dilapidated housing, and high contact with immigrants in the absence of the other risk factors (1^1^1^1^0^0); and (4) absence of risk factors for TB transmission (0^0^0^0^0^0).

Asians. Class 1. For Asians, the most common configuration in zip codes with very high TB rates was the absence of high exposure to poverty and overcrowded and dilapidated housing (0^0^0).

Class 2. The absence of risk factors was the norm in zip codes with very high TB rates (0^0^0^0^0^0).

Discussion

This study showed zip code–level risk factors associated with very high TB rates in New Jersey during a period (1985–1992) when this disease was on the rise. As suggested by epidemiologic theory, population-level characteristics are important determinants of infectious disease transmission at the population level. I used 3 measures of exposure to known risk factors for TB transmission (i.e., poverty, overcrowded housing, and dilapidated housing) and 3 measures of contact and density patterns (i.e., contact with immigrants, isolation, and own-group density) to characterize zip codes with very high TB rates.

Zip code–level risk factors associated with very high TB rates varied by racial/ethnic group. For Whites and Asians, risk factors were rare (i.e., for these groups, the living environment in these zip codes may not have been conducive to TB transmission). In agreement with the distribution of TB cases by age and foreign-born status (Table 1), this suggests that cases among Whites may have been due to reactivation, whereas cases among Asians may have been imported. In contrast, for Hispanics and African Americans, very high TB rates were associated with risk factors that may facilitate TB transmission. African Americans were the group most frequently exposed to multiple risk factors.

Isolation appears to have had protective effects for Whites but detrimental effects for African Americans. In contrast with White isolation, African American isolation often

TABLE 3—Risk Factors Associated With Very High Tuberculosis (TB) Rates, by Race/Ethnicity: Proportion of No, Low, High, and Very High TB Zip Codes That Fulfill Simple and Complex Boolean Statements, New Jersey, 1985–1992

	No TB	Low TB	High TB	Very High TB
Non-Hispanic Whites				
EP≥0.20	1.3	0.0*	0.0*	6.0
EC≥0.10	1.3*	0.0*	0.0*	13.0
ED≥0.65	1.3*	0.0*	2.0*	18.0
CI≥0.20	2.7*	1.0*	4.0*	32.0
P≥0.60	95.3*	100.0*	98.9*	74.0
PD≥5100	0.0*	0.0*	2.0*	14.0
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)				
0 0 0	97.3*	100.0*	98.0*	80.0
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)^(CI≥0.20)^(P≥0.60)^(PD≥5100)				
0 0 0 0 1 0	93.3*	99.0*	95.0*	58.0
African Americans				
EP≥0.20	1.3*	15.6*	11.1*	53.3
EC≥0.10	0.6*	4.4*	11.1*	64.4
ED≥0.65	5.4*	6.7*	8.9*	68.9
CI≥0.20	6.3*	2.2*	11.1*	31.1
P≥0.60	0.3*	8.9*	22.2	42.2
PD≥5100	0.0*	0.0*	6.7*	37.8
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)				
1 1 1	0.3*	0.0*	2.2*	42.2
0 0 0	93.7*	75.6*	77.8*	20.0
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)^(CI≥0.20)^(P≥0.60)^(PD≥5100)				
1 1 1 0 1 1	0.0*	0.0*	2.2	11.1
1 1 1 1 0 0	0.0*	0.0*	0.0*	11.1
0 0 0 0 0 0	88.1*	68.9*	55.6*	11.1
Hispanics				
EP≥0.20	1.6*	20.0	17.7*	41.2
EC≥0.10	1.1*	22.9*	35.3	61.8
ED≥0.65	2.4*	14.3*	29.4*	61.8
CI≥0.20	3.2*	37.1*	29.4*	73.5
P≥0.60	0.3*	5.7	5.9	8.8
PD≥5100	0.0*	5.7	11.8	17.7
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)				
1 1 1	0.3*	0.0*	11.8*	41.2
0 0 0	95.7*	60.0	55.9	35.2
0 1 1	0.0*	5.7	8.8	17.7
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)^(CI≥0.20)^(P≥0.60)^(PD≥5100)				
0 0 0 1 0 0	3.2*	20.0	5.9	20.6
0 1 1 1 0 0	0.0*	0.0*	2.9	14.7
1 1 1 1 0 0	0.0*	0.0*	2.9	14.7
0 0 0 0 0 0	92.5*	40.0*	50.0*	14.7
Asians				
EP≥0.20	2.1	0.0	2.4	7.1
EC≥0.10	3.6*	2.4*	7.1	19.9
ED≥0.65	3.9*	9.5*	4.8	21.4
CI≥0.20	5.0*	35.7	23.8	45.2
P≥0.60	0.0	0.0	0.0	0.0
PD≥5100	0.0	0.0	0.0	0.0
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)				
0 0 0	92.9*	90.5	90.5	76.2
0 1 1	0.4*	2.4	2.4	11.9
(EP≥0.20)^(EC≥0.10)^(ED≥0.65)^(CI≥0.20)^(P≥0.60)^(PD≥5100)				
0 0 0 0 0 0	90.4*	64.3	73.8	54.8
0 0 0 1 0 0	2.5*	26.2	16.7	21.4
0 1 1 1 0 0	0.4*	2.4	2.4	11.9

Note. EP = exposure to poverty; EC = exposure to crowded housing; ED = exposure to dilapidated housing; CI = contact with immigrants; P = isolation; PD = partial density.

*Difference in proportions between the very high TB group and each of the other 3 groups was statistically significant, $P \leq .05$ (after Bonferroni adjustment).

occurred in combination with low-quality and high-density living environments.

Analyses of infectious diseases often focus on high-risk groups, in which risk is determined by individual-level characteristics (e.g., homeless status). With this article, I hope to highlight the role of *context* in the epidemiology of infectious diseases and to suggest that high risk also may be defined in ecologic terms. □

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