Tuberculosis and Race/Ethnicity in the United States
Impact of Socioeconomic Status

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Despite the long-standing observation that tuberculosis (TB) case rates are higher among racial and ethnic minorities than whites in the United States (U.S.), the proportion of this increased risk attributable to socioeconomic status (SES) has not been determined. Values for six SES indicators (crowding, income, poverty, public assistance, unemployment, and education) were assigned to U.S. TB cases reported from 1987–1993 by ZIP code- and demographic-specific matching to 1990 U.S. Census data. TB risk between racial/ethnic groups was then evaluated by quartile for each SES indicator utilizing univariate and Poisson multivariate analyses. Relative risk (RR) of TB increased with lower SES quartile for all six SES indicators on univariate analysis (RRs 2.6–5.6 in the lowest versus highest quartiles). The same trend was observed in multivariate models containing individual SES indicators (RRs 1.8–2.5) and for three SES indicators (crowding, poverty, and education) in the model containing all six indicators. Tuberculosis risk increased uniformly between SES quartile for each indicator except crowding, where risk was concentrated in the lowest quartile. Adjusting for SES accounted for approximately half of the increased risk of TB associated with race/ethnicity among U.S.-born blacks, Hispanics, and Native Americans. Even more of this increased risk was accounted for in the final model, which also adjusted for interaction between crowding and race/ethnicity. SES impacts TB incidence via both a strong direct effect of crowding, manifested predominantly in overcrowded settings, and a TB-SES health gradient, manifested at all SES levels. SES accounts for much of the increased risk of TB previously associated with race/ethnicity. Cantwell MF, McKenna MT, McCray E, Onorato IM. Tuberculosis and race/ethnicity in the United States: impact of socioeconomic status.

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Nationwide surveillance of tuberculosis (TB) mortality, which began in 1900, and of incident TB cases, which began in 1953, has consistently demonstrated that the burden of TB in the United States (U.S.) falls disproportionately on members of racial/ethnic minorities (1). Tuberculosis case rates among Hispanics, blacks, and Asian/Pacific Islanders, for example, were 5.5, 8, and 11.5 times higher, respectively, than those among whites from 1985–1992 (1). In order to explain these observations, numerous theories have been advanced attributing racial/ethnic differences in TB morbidity and mortality to a variety of factors, including physical characteristics, such as body weight and chest size, ABO blood type, skin color and absorption of vitamin D, and potential differences in susceptibility to tuberculosis infection (2–4). An equally, if not more, plausible explanation, however, is that much of the increased risk of TB among racial/ethnic minorities is due, not to intrinsic genetic differences but rather, to confounding by social and economic factors that increase risk of exposure to TB and are more common among these minorities. Although TB has long been linked to low socioeconomic status (SES) (2, 5), previous studies frequently focus on only the poorest members of society and often did not evaluate the impact of SES on the relationship between race/ethnicity and TB. In our study, we investigated the interaction between increased risk of TB and multiple factors, including SES, race/ethnicity, and birthplace, using multivariate regression models.

METHODS

From the U.S. Bureau of the Census, we obtained 1990 U.S. Census data by ZIP code for the following SES indicators: (*1*) median number of persons per room per household (crowding); (*2*) median household income (income); (*3*) percentage of persons living below the poverty level (poverty); (*4*) percentage of persons receiving public assistance income (public assistance); (*5*) percentage of persons 16–65 yr-old who were unemployed (unemployment); and (*6*) percentage of persons ⩾ 25 yr-old who had completed high school (education). The Census data were further stratified by the following four demographic variables: (*1*) age group (0–4, 5–14, 15–24, 25–44, 45–64, and ⩾ 65 yr-old); (*2*) sex; (*3*) race/ethnicity (non-Hispanic whites [whites], non-Hispanic blacks [blacks], Native Americans/American Indians [Native Americans], Hispanics, and Asians/Pacific Islanders [Asians]; and (*4*) country of birth (foreign-born and U.S.-born). Reporting of incident TB cases to the Centers for Disease Control and Prevention (CDC) includes demographic and geographic data, with ZIP-code area of residence the smallest geographic unit reported. We matched each TB case reported to the CDC from the 50 states and District of Columbia from 1987–1993 to the Census database by ZIP code and the four de-

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TABLE 1

VALUES COMPRISING SES QUARTILES FOR EACH SES INDICATOR

SES Indicator	Values Comprising SES Quartiles			
	1st	2nd	3rd	4th
Crowding	⩽ 0.43	0.44–0.59	0.60–0.70	⩾ 0.71
Income†	⩾ $47,500	$35,000–$46,499	$27,500–$34,999	⩽ $24,499
Poverty‡	⩽ 3.7%	3.8–8.1%	8.2–16.8%	⩾ 16.9%
Public Assistance¶	⩽ 2.5%	2.6–5.3%	5.4–10.5%	⩾ 10.6%
Unemployment‖	⩽ 3.6%	3.7–5.2%	5.3–7.9%	⩾ 8.0%
Education**	⩾ 87.1%	78.4–87.0%	67.4–78.3%	⩽ 67.3%

* Median number of persons per room.
† Median household income.
‡ Percent living below poverty level.
¶ Percent receiving public assistance.
‖ Percent unemployed, 16–64 yr old.
** Percent high school graduates, ⩾ 25 yr old.

mographic variables, as stratified previously. We then assigned the proxy values for the six SES indicators to each TB case that corresponded to the calculated value for each demographic and ZIP-code specific group. Only TB cases that matched completely to the Census database were included in the multivariate analyses. To avoid underestimation of TB case rates for univariate analyses we derived a weighted case count by multiplying the case count for each age, sex, race/ethnicity, country of birth, and state of residence specific group by the inverse of the proportion of cases that matched to a ZIP code in each group.

For each SES indicator, the total U.S. population was sorted by ZIP-code-specific demographic substratum values and then divided into SES quartiles, with the first (highest) SES quartile containing the 25% of the population with the highest SES values for the indicator and so on to the fourth (lowest) SES quartile. We used age-adjusted univariate analyses to determine TB case rates by SES quartile for each of the six SES indicators. We evaluated the association between SES indicators and probability of being a case of TB utilizing a series of Poisson multivariate regression models. The "demographic" model contained only the four demographic variables, stratified as above. The six "simple SES" models contained the demographic model and one SES indicator variable each. The "combined SES" model contained the demographic model and all six SES indicators. Interaction was evaluated by adding race/ethnicity-SES indicator joint covariates to the combined SES model. All significant interaction joint covariates, i.e., variables that once added, changed the coefficient of the respective SES indicator in the combined SES model by ⩾ 20% (6), were added to the combined SES model to produce the "final" SES model. The final model contained age, race, and all the SES indicators as continuous scored variables (one through four) and an interaction term between race and crowding. Otherwise, relative risks with 95% confidence intervals excluding 1.0 were considered statistically significant.

RESULTS

There were 172,231 cases of TB reported to the CDC from 1987–1993. Of these, 159,070 (92.8%) matched completely to

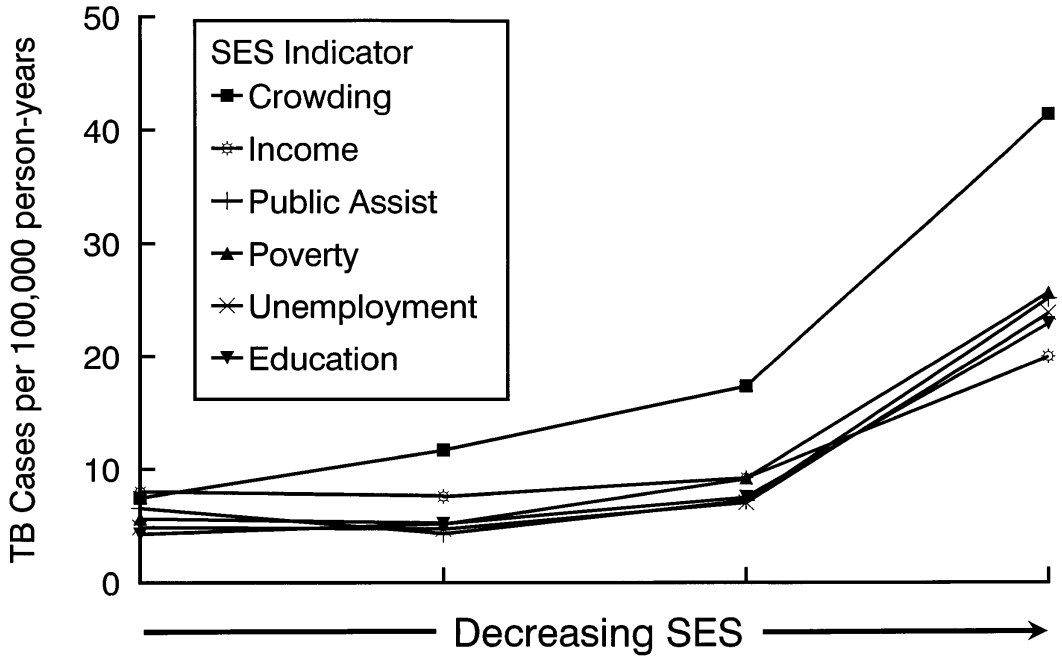

Figure 1. TB case rates by SES indicator, 1987–1993. Rates are age-adjusted to 1990 total U.S. population.

TABLE 2

TB RATE RATIOS BY SES INDICATOR AND SES QUARTILE

	TB Rate Ratios by SES Quartile (*compared to 1st SES quartile*)					
	Simple SES Models			Combined SES Model		
SES Indicator	2nd	3rd	4th	2nd	3rd	4th
Crowding	1.0	1.3*	2.2*	0.9	1.1	1.7*
Income	1.4*	1.6*	2.1*	1.0	1.0	1.0
Poverty	1.2*	1.6*	2.3*	1.2*	1.3*	1.5*
Public Assistance	1.0	1.2*	1.8*	0.9	1.0	1.2*
Unemployment	1.2*	1.4*	2.0*	1.1*	1.1*	1.2*
Education	1.5*	2.0*	2.5*	1.3*	1.4*	1.5*

* Denotes statistical significance, based on a 95% CI not including 1.0.

the Census database by ZIP code and all four demographic variables. For each SES indicator, the range of values constituting each SES quartile are shown in Table 1.

On univariate age-adjusted analysis, TB case rates increased with lower SES quartile for each indicator (rate ratios [RRs] 2.5–5.6 in the fourth [lowest] versus the first [highest] SES quartiles) (Figure 1). The relative and absolute magnitude of this association was greatest for crowding, with case rates per 100,000 person-years of 41.6 and 7.4 in the fourth (lowest) and first (highest) SES quartiles, respectively.

For the simple and combined SES models, the rate ratios for the second through fourth (lowest) SES quartiles are shown relative to the first (highest) SES quartile for each SES indicator in Table 2. The 95% CIs for these rate ratios are not shown since all were ≤ 0.1 in either direction, although CIs that included 1.0 are noted in the table. In the simple SES models, risk of TB increased with lower SES quartile for each SES indicator (RRs 1.8–2.5 in the fourth [lowest] versus the first [highest] SES quartile). In the combined SES model, risk of TB increased with lower SES quartile for crowding, poverty, and education. In both the simple and combined SES models, rate ratios increased at a relatively constant rate between SES quartiles for each indicator except crowding. For crowding, the increased TB risk was much higher in the lowest (fourth) SES quartile than in all other quartiles.

Table 3 compares RRs for the demographic and combined SES models for each racial/ethnic group compared with whites for both foreign-born and U.S.-born individuals. Adjustment for the six SES indicators in the combined SES model reduced the rate ratios associated with race/ethnicity in the demographic model by approximately one-half for U.S.-born blacks, Hispanics (both foreign- and U.S.-born), and Native Americans but had relatively little impact among foreign-born blacks and Asians (both foreign- and U.S.-born).

Significant interaction between race/ethnicity and SES indicators was noted only for crowding. Among U.S.-born individuals in the final SES model, the RRs of TB compared with whites among blacks, Hispanics, and Native Americans were only 2.1, 1.6, and 1.9, respectively, among individuals in the first (highest/least crowded) quartile, much less than the RRs of 9.6, 6.5, and 4.6, respectively, among all U.S.-born individuals in these three groups in the demographic model, which did not adjust for SES. Among U.S.-born individuals in the final SES model, the effect of interaction with crowding was greatest among blacks, where TB risk compared with whites was over three times higher in the fourth (lowest/most crowded) quartile compared with the first (highest/least crowded) quartile. Detailed stratified analysis demonstrated that there was a three way interaction between age, race and crowding within the U.S.-born population. In U.S.-born persons less 45 years of age RRs (95% CIs) for TB in blacks compared with whites from a combined model increased from 1.8 (1.7–2.0) in the least crowded quartile to 6.0 (5.8–6.2) in the most crowded. However, in the older, U.S.-born population the black to white differential changed very little, decreasing from 2.2 (2.1–2.3) in the least crowded to 1.9 (1.8–2.0) in the most crowded quartile.

DISCUSSION

The burden of morbidity and mortality due to TB in the U.S. has long been noted to fall disproportionately on racial/ethnic minorities (1, 2, 4, 6). In our study we found that, even after adjusting for age, sex, and country of birth, TB rates among racial/ethnic minorities were 5–10 times higher than those in whites from 1987–1993. Despite the longstanding nature of the evidence documenting the increased TB risk among racial/ethnic minorities in the U.S., there is currently no satisfactory explanation for these observed differences.

Although most previous studies sought to explain the increased risk of TB among racial/ethnic minorities through intrinsic, genetically related factors, we attempted to determine the interaction with SES, an extrinsic factor long associated with risk of TB. Low SES has frequently been linked to increased risk of TB, especially among those living in crowded settings (2, 5), such as crowded households (7, 8), congregate living facilities, e.g., homeless shelters, long-term nursing facilities, and correctional facilities (9), and more crowded urban

TABLE 3

TB RATE RATIOS BY RACIAL/ETHNIC GROUP AND PLACE OF BIRTH DEMOGRAPHIC* AND COMBINED* SES MODELS

	Foreign-born		U.S.-born	
	Demographic (95% CI)†	Combined (95% CI)†	Demographic (95% CI)†	Combined (95% CI)†
Race/ethnicity				
White	Baseline	Baseline	Baseline	Baseline
Black	7.3 (7.3–8.0)	5.3 (5.1–5.6)	9.6 (9.4–9.7)	4.4 (4.3–4.5)
Hispanic	5.7 (5.5–5.9)	3.0 (2.9–3.2)	6.5 (6.4–6.6)	2.8 (2.7–2.9)
Asian	11.2 (11.0–11.4)	8.1 (7.8–8.5)	3.8 (3.6–4.0)	3.5 (3.3–3.7)
Native American	—	—	4.6 (4.4–4.9)	2.3 (2.2–2.4)

* Demographic models included only age, race/ethnicity, sex, and birthplace. All six SES indicators were included with the demographic variables in the combined model.

† Rate ratios compare risk in the designated racial/ethnic group to that in whites within each model. CI denotes confidence interval.

TABLE 4

TB RATE RATIOS BY RACIAL/ETHNIC GROUP AND 1st AND 4th CROWDING QUARTILES: FINAL SES MODEL (U.S.-BORN ONLY)

	Crowding Quartile	
Race/Ethnicity	1st (*Highest*) (95% CI)*	4th (*Lowest*) (95% CI)*
White	Baseline	Baseline
Black	2.1 (2.2–2.3)	7.0 (6.8–7.3)
Hispanic	1.6 (1.5–1.7)	4.1 (3.8–4.5)
Asian	3.3 (3.0–3.7)	4.5 (3.8–5.3)
Native American	1.9 (1.7–2.2)	3.6 (3.0–4.2)

* Rate ratios compare risk in the designated racial/ethnic group to that in whites within the 1st (highest) and 4th (lowest) SES quartiles for crowding in the final SES model, i.e., the combined SES model with race/ethnicity-crowding interaction variable. CI denotes confidence interval.

versus rural settings (1, 5). Less frequently, other indicators of low SES, such as poverty (8), receipt of public assistance income (8), and unemployment (7), have also been associated with increased TB risk. In our study, we found that risk of TB increased with lower SES for all the SES indicators evaluated, with crowding having the greatest impact. The absolute case rates are not significantly different for the SES indicators, with the exception of crowding. The higher rates of TB associated with crowding has a plausible biologic explanation in that there is a greater degree of shared airspace in crowded living quarters, which would increase exposure to *Mycobacterium tuberculosis*. Our results suggest that SES influences TB risk by at least two separate mechanisms, the first a strong effect directly attributable to crowding and manifested predominantly in overcrowded settings and the second, evident for all the other SES indicators evaluated, a previously unrecognized SES–health gradient, in which TB risk increases at a relatively constant rate with decreasing SES across the entire SES spectrum. Similar SES–health gradients have been described for aggregate mortality and other specific diseases, such as coronary heart disease, hypertension, cancer, and many chronic diseases (10).

Several early studies suggested that low SES was an important contributor to the increased risk of TB among blacks in the U.S. (2, 11). Our study is the first to examine this connection using national surveillance data and multivariate methods to explore the relationships between demographic characteristics and SES indicators. We found that adjusting for the six SES indicators accounted for approximately half the increased risk of TB previously ascribed to race/ethnicity among U.S.-born blacks, Hispanics, and Native Americans. Adjusting for SES had relatively less effect among foreign-born blacks and Asians, suggesting that other factors, such as increased TB exposure, either overseas or in the U.S. as a result of contact with TB cases arising from reactivation of infection acquired overseas, are relatively more important TB risk factors in these groups. Rates of TB in Asian countries are several-fold higher than in other parts of the world and the tendency of immigrants to the U.S. to settle in or be resettled in areas with other immigrants increases exposure to *M. tuberculosis* above that in other areas of the U.S. (13).

Early studies had suggested that the magnitude and pattern of the increased TB risk associated with decreasing SES was similar between racial/ethnic groups (2, 12). Our study corroborated this finding for all the SES indicators evaluated except crowding, where the impact on TB risk was relatively greater among blacks, especially those younger than 45 yr of age. The higher prevalence of multiple known risk factors for TB among younger blacks living in crowded conditions, such as homelessness, alcoholism, incarceration, intravenous drug use, and infection with human immunodeficiency virus (HIV), most likely accounted for much of the accentuated effect of crowding in this population (14). Additional adjustment for interaction between race/ethnicity and crowding in the final model further increased the proportion of TB risk accounted for by SES, especially among U.S.-born blacks. Among U.S.-born individuals in the final model, TB risk among blacks, Hispanics, and Native Americans in the highest (least crowded) quartile was only approximately twice that of whites, dramatically lower than the 5–10 times higher risk demonstrated in these groups prior to adjusting for SES. Many social components of racial and ethnic categories other than genetically determined susceptibility to tuberculous infection probably explain the residual twofold increased risk in the highest SES group (15). Increased exposure to TB in minorities could result from preferential association with persons of similar racial and ethnic backgrounds who are at increased risk of this disease (e.g., homeless, substance abusers, etc.) regardless of the SES status of the minority subgroup. Other factors, especially HIV, which are not equally distributed between racial/ethnic groups, could increase the risk of progression to active disease. The methodology we used to assign SES values to TB cases, which will be discussed below, could also result in some residual confounding. Finally, the three-way interaction between white versus black race, age, and crowding suggest that such time related effects are important. An individual's risk of active disease is dependent on a lifetime history of exposure, not just their current SES status as was measured in our study. Hence, the greater upward socioeconomic mobility of minority groups since the civil rights movement will mean that a larger portion of blacks in a high SES category will have experienced poverty, and a greater risk of TB exposure, in their earlier lives.

Previous studies linking TB and SES frequently did not control for the impact of demographic characteristics and the potential for confounding between SES indicators. While our current study used multivariate modeling to avoid these limitations, it still shares two other important methodological limitations with previous studies. The first is that, since all these studies are ecological analyses, they may erroneously assign group-based measures of disease-exposure association to individuals within the group, i.e., the ecological fallacy, and/or tend to inherently overestimate the strength of the exposure-disease association (16). The second shared limitation is the potential for error introduced by assigning SES values to persons with TB based on median values for their demographic counterparts within a given geographic area, e.g., ZIP code. Given the high rates of TB among various subpopulations commonly associated with low SES, e.g., the homeless, alcoholics, intravenous drug users, persons who have been incarcerated, and persons living in medically-underserved urban area (5, 9), persons with TB have long been assumed to be of relatively lower SES than their demographic and geographic counterparts. Assigning SES values to persons with TB based on median/mean values for their demographic and geographic counterparts, therefore, would tend to, perhaps markedly, underestimate the true magnitude of the association between SES and TB.

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