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Source: *Social Science History*, Winter, 1983, Vol. 7, No. 1 (Winter, 1983), pp. 31-59

Published by: Cambridge University Press

Stable URL: https://www.jstor.org/stable/1171033

Mortality Variation in U.S. Cities in 1900

A Two-Level Explanation by Cause of Death and Underlying Factors

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Health conditions in United States cities at the turn of the twentieth century were very poor. Bleak pictures of crowded dwellings, contaminated water supplies, and filthy streets have been painted by numerous observers of urban areas at the time (Smith, 1964). While the effects of these conditions on mortality levels have not been precisely measured, urban mortality rates were consistently higher than rural mortality rates in 1900 in the United States (Condran and Crimmins, 1980). Nevertheless, considerable variation in the mortality levels of different cities also existed. Our goal in this article is to explain the variation in the mortality conditions in U.S. cities for which death registration data were collected in 1900. The analysis is done in two stages. First, the causes of death which accounted for the different mortality levels are isolated. Second, a multivariate analysis of the factors affecting the rates of occurrence of these causes of death is performed.

Authors' Note: *This research was supported by grants from the National Institute of Aging (PHS AG 02699-01) and from the Center for Population Research, National Institute for Child Health and Human Development (R0 1 HD 12413). The latter grant is held at the Philadelphia Social History Project, Theodore Hershberg, Director.*

THE MORTALITY DATA

The urban death rates for certain age groups and for the selected causes of death used in this article were calculated from data published in the federal census of 1900 for 126 cities over 25,000 in population (see the Appendix). For a number of the cities in our analysis, registration data were supplemented with returns from an enumeration of deaths carried out during the federal census in 1900; however, for all cities in this analysis, over 90% of the reported deaths were from city registration systems. Base population figures used in the calculation of mortality rates were collected in the federal census of 1900. Of the 126 cities in the analysis, 108 are in the northern and western sections of the country and 18 are in the South.

THE CAUSES OF DEATH ACCOUNTING FOR THE VARIATION IN URBAN MORTALITY

Cause-specific death rates for the individual cause-of-death categories available in the census and for causes of death grouped according to their primary modes of transmission are presented in Table 1, panel 1. The cause-specific death rates are averaged across all cities, and also separately for southern cities and cities outside the South. The analysis is presented separately for these two major regions of the country because southern mortality rates were clearly higher than northern and western mortality rates at this time (Yasuba, 1962; Meeker, 1970) and the cause-of-death structure is known to vary with the level of mortality (Preston, 1976).

More than 25% of all deaths in the cities were due to specific airborne diseases. Tuberculosis was the most important of the airborne diseases, accounting for approximately 40% of the deaths in that category. Diseases which have been identified as primarily water- and foodborne, for example, typhoid fever and diarrheal diseases,[1] accounted for 10% of the total deaths.

Table 1 Cause-Specific Death Rates and Percentage Contribution of Individual Causes to Intercity Variation in Mortality Rates from All Causes: Registration Cities, 1900

	1. Cause-Specific Death Rates* (per 100,000 population)			2. Percentage Contribution of Individual Causes of Death to the Inter-City Variation in Mortality Rates from All Causes		
	(a) All Cities	(b) Northern and Western Cities	(c) Southern Cities	(a) All Cities	(b) Northern and Western Cities	(c) Southern Cities
Selected Air-Borne:	473.0	446.1	636.1	26.7	34.3	20.0
Measles	9.7	9.5	11.2	0.7	1.6	0.1
Scarlet Fever	10.0	11.0	4.3	0.0	0.8	-0.1
Diphtheria & Croup	46.1	47.9	35.7	0.1	3.3	-2.5
Whooping Cough	13.6	12.9	18.1	0.7	0.8	0.8
Influenza	25.4	23.6	36.6	2.0	1.5	3.7
Pneumonia	174.7	168.7	209.0	8.2	13.9	4.3
Tuberculosis	193.8	172.5	321.2	15.0	12.4	13.7
Selected Water- & Food-Borne:	179.6	163.8	274.2	12.7	11.9	12.6
Diarrheal Diseases	138.1	126.7	206.4	10.7	11.5	11.0
Typhoid Fever	41.5	37.1	67.8	2.0	0.4	1.6
Selected Vector-Borne:	13.2	4.7	64.4	4.6	0.3	7.4
Malaria	13.2	4.7	64.4	4.6	0.3	7.4
Other Disease Categories:						
Cancer & Tumor	61.1	61.2	60.6	0.5	1.3	0.4
Heart Disease & Dropsy	137.0	130.3	177.6	5.6	5.2	6.3
Diseases of the Liver	21.5	19.8	31.5	1.3	1.5	0.5
Diseases of the Nervous System	225.3	213.6	295.7	10.9	12.7	9.5
Diseases of the Urinary System	93.1	85.0	141.7	6.9	5.0	10.5
Afflictions Connected with Pregnancy	11.8	10.9	17.3	0.6	0.3	0.6
Old Age	49.2	45.6	70.7	2.2	1.7	1.3
All Other Causes (Residual):	512.3	484.7	677.4	25.1	25.6	27.5
Unknown:	21.5	16.0	54.3	2.8	0.4	3.4
Total — All Causes:	1798.8	1681.7	2501.6	99.9	100.2	100.0
	N=126	N=108	N=18	N=126	N=108	N=18

SOURCE: U.S. Census Office, 1902b: 285-555.
*Unweighted means of city cause-specific death rates.

Malaria, the only vectorborne disease listed separately in the census, as shown in Table 1, accounted for 2.6% of the deaths in southern cities but was numerically insignificant in the North. the airborne, water- and foodborne, and vectorborne disease categories combined comprised 37% of all deaths. The other disease groups listed in the 1900 census include both infectious and noninfectious diseases and have not been classified by mode of transmission. The first two in Table 1 (cancer and tumor, and heart disease and dropsy) were primarily noninfectious; the remaining, including the residual (all other causes), were probably a combination of infectious and noninfectious diseases.[2]

Mortality rates for the airborne, waterborne and foodborne, and vectorborne disease categories, as well as for the residual category of cause of death, were higher in southern cities than in northern and western cities. Southern rates of death from certain diseases, however, did not exceed those in cities outside the South: the mortality from scarlet fever and diphtheria and croup were lower in the South than in the North and West, while the rates from measles and cancer and tumor were virtually the same in the cities in the two regions. For most individual diseases, however, the rates in southern cities were greater than those in northern and western cities. Among specific causes of death, tuberculosis, diarrheal diseases, and diseases of the nervous system showed the largest regional differences and were most important in accounting for the excess mortality of southern cities over northern and western cities.

Contained in Table 1, panel 2, is the percentage of the variation in the cities' total mortality rates explained by each cause-of-death category and by causes grouped according to their modes of transmission. The contribution of each cause-of-death category to variation in the crude death rates across cities is estimated by regressing the crude death rate on the death rate from each cause.[3] Airborne diseases accounted for approximately one-quarter of the variation in total mortality rates across all cities, the water- and foodborne for 13%, and the vectorborne disease for 5% of the variation in total mortality rates. Another quarter of the variation was accounted for by the residual category, other diseases. Among the specific disease categories shown in Table 1, tuberculosis contributed most to the variation in mortality across all cities, followed by diarrheal diseases and diseases of the nervous system.

The importance of certain disease categories in accounting for variation in total death rates was different in the South than in the North and West. Pneumonia contributed more to the variation in mortality rates outside the South; malaria and diseases of the urinary system were more important sources of variation among southern cities.

AGE STRUCTURE AND CAUSE OF DEATH

The cause-specific death rates used to calculate the proportion of variation explained by different causes of death in the preceding tables may have been affected by the age distribution of the cities' populations. Some of the variation in death rates by cause may have resulted from the concentration of a disease in one age group and the variation across cities in the proportion of the population in that age group. Because cause-specific mortality rates over the full range of ages were not published for the group of cities in our analysis, direct age standardization of the cause-specific rates was not possible. In previous work on U.S. cities in 1890, we were able to use age-standardized mortality rates to attribute the variation in total mortality across 28 large cities to individual causes of death (Condran and Crimmins-Gardner, 1976). In this earlier analysis, the conclusions reached using age-standardized rates were similar to those using unstandardized rates, although some small differences existed in the proportions of variation explained by individual causes of death.

We have calculated death rates by cause for two age groups in 30 of the 108 northern and western cities with 1900 mortality data. The 30 cities for which age- and cause-specific death rates were available all had over 100,000 in population in 1901 and may not be representative of the registration cities used in the remainder of the analysis. In addition, the causes of death published for these cities were not identical to those available for the larger group of cities. Average death rates by cause for the 30 cities for infants and for adults 20-29 years old are shown in Table 2. The 20-29 year age group is not ideal for the task at hand, but it is the oldest age group for which the data on populations and deaths were published in comparable form. We have chosen to examine infant deaths in spite of the fact that they were more likely to be under-registered than were deaths in other age groups. Our purpose in

Table 2 Cause-Specific Death Rates and Percentage Contribution of Individual Causes to Intercity Variation in Mortality Rates from All Causes for All Ages, Infants, and Adults 20-29: Selected Northern and Western Registration Cities, 1900

	1. Cause-Specific Death Rates* (per 100,000 population)			2. Percentage Contribution of Individual Causes of Death to the Inter-City Variation in Mortality Rates from all Causes		
	Total	Infants	20-29	Total	Infants	20-29
Selected Air-Borne:	556.1	3545.2	375.8	42.1	17.1	55.7
Measles	12.0	150.3	0.5	2.0	1.3	0.0
Scarlet Fever	15.1	28.7	1.3	1.7	0.3	0.1
Diphtheria & Croup	45.5	123.9	2.5	3.4	0.3	-0.1
Whooping Cough	11.6	270.8	0.0	0.8	0.7	0.0
Diseases of the Respiratory System	276.8	2832.8	82.0	19.8	13.8	7.1
Respiratory Tuberculosis	195.1	138.7	289.5	14.4	0.7	48.6
Selected Water- & Food-Borne:	184.6	4176.8	70.4	13.5	39.3	17.4
Diarrheal Diseases	148.1	4168.0	14.5	12.1	39.3	7.1
Typhoid Fever	36.5	8.8	55.9	1.4	0.0	10.3
Other Disease Categories:						
Cancer & Tumor	63.1	9.5	8.6	1.3	0.1	0.8
Disease of Heart, Circulatory System	141.5	193.7	44.2	8.3	0.0	3.0
Diseases of the Nervous System	207.9	2457.0	38.5	6.2	3.6	0.5
Diseases of the Urinary System	102.1	181.4	44.5	7.4	-0.9	0.8
Afflictions of Pregnancy	13.0	0.0	31.1	0.7	0.0	-1.4
Old Age	42.2	0.0	0.0	-1.9	0.0	0.0
Afflictions of Birth	103.7	4784.4	0.1	5.6	25.6	0.0
Other Epidemic Diseases	29.3	175.5	9.1	2.6	0.8	0.9
All Other Causes:	353.5	2436.2	205.7	14.0	14.9	22.1
Total — All Causes:	1797.0	17959.7	828.0	99.8	100.5	99.8

N = 30

SOURCE: See Table 1.
*Unweighted means of city cause-specific death rates.

this section is to determine whether the causes of death accounting for the variation in the overall city mortality rate differed by age. It is unlikely that underregistration varied enough by cause to change the relative importance of various causes of infant deaths in these cities, even though the reported infant mortality rates may be low. In addition, because infant deaths are usually more numerous than deaths in any other age group, it is helpful in interpreting the variance in cause-of-death data grouped for all ages to know which causes might be underregistered because they are concentrated among infants.

There are striking differences in the causes of death accounting for mortality variation in the two age groups. Airborne diseases accounted for over three times as much of the variation in the adult mortality rate as in the infant mortality rate (55.7% versus 17.0%). In contrast, water- and foodborne diseases accounted for over twice as much of the variation in infant rates as in adult rates (39.3% versus 17.3%). In large part these differences reflect the importance of a few causes of death in the mortality rates of the two age groups. Tuberculosis of the lungs, numerically the most important cause of death among 20-29 year olds, accounted for almost half (48.6%) of the variation across cities in the total death rate of this group. On the other hand, this disease category accounted for almost none (0.7%) of the variation in infant mortality. The death rate from diarrheal diseases among infants was the second largest cause of infant deaths. These diseases accounted for the largest percentage (39.3) of the variance across cities in infant deaths, but explain only 7.1% of the variation in the adult death rate. Typhoid fever, the other identifiable water- and foodborne disease, was associated only with the variation in adult mortality. The category "afflictions of birth," which contained congenital defects and malformations, was the most important cause of death among infants and accounted for about one-quarter (25.6%) of the variation in infant mortality rates.

SUMMARY

We can draw a number of conclusions from this analysis. First, infectious diseases predominated as the cause of variation in city crude death rates in 1900. About half of the variation in crude death rates in northern and western cities and in southern cities was due to variation in the specified airborne, water- and foodborne, and vectorborne diseases. Much of the rest was due to variation in diseases having an infectious component. Very little variation was due to clearly noninfectious diseases such as cancer. Second, among the specified diseases only a few, namely pneumonia, tuberculosis, diarrheal diseases, and diseases of the nervous system, individually explained a large amount of the variation in the crude death rate. Third, while infectious diseases predominated as the cause of both infant and young adult mortality, different individual causes of death were responsible for the variation in infant and adult city death rates. Fourth, the contribution of each disease to the variation in death rates was not identical in the North and West and in the South.

THE VARIATION IN URBAN MORTALITY: THE EFFECT OF UNDERLYING VARIABLES ON SPECIFIC CAUSES OF DEATH

PREVIOUS RESEARCH

The cities included in our analysis differed in population size and composition, density, climate, levels of living, housing characteristics, and water purity. In previous research, all of these characteristics of urban areas have been linked both theoretically and empirically to the variation in mortality rates of U.S. cities during this time period (Meeker, 1970; Higgs and Booth, 1979). Using a sample of cities similar to the sample used in this article, Meeker (1970) related city crude death rates for 1890 and 1900 to a number of variables. He found that crowding and southern location were positively related to mortality at both dates, while literacy was negatively related to mortality in 1900, the only date for which it was included in his analysis.

Higgs and Booth (1979) examined the relationship between mortality and a number of variables for wards of 17 large cities in 1890. They used two measures of mortality in their analysis, the death rate of children aged 1 to 4 and of persons aged 5 and above. The effects of the independent variables differed for these two groups. Although crowding and density were positively related to both adult and child mortality, the effect of each was stronger on the childhood death rate than on the adult death rate. Water purity was negatively related to both childhood and adult mortality, but again more strongly to childhood mortality.

This article builds on the work of Meeker and of Higgs and Booth by relating city cause-specific mortality rates to a number of independent variables through regression analysis. With city-level data we can use more refined mortality rates than Higgs and Booth used. In addition, having isolated the causes of death accounting for the variation in city crude death rates, we can tailor our analysis to causes of death, differing in their modes of transmission. Cause-specific death rates are regressed where appropriate on indicators of density, crowding, the provision of pure water, ethnicity, inmigration, and levels of living. The analysis is ecological in nature; therefore, hypotheses and explanations that depend on individual-level relationships must remain speculative.

THE MODEL

Because infectious diseases predominated as a cause of urban mortality variation at the beginning of the twentieth century, much of the difference in city mortality levels can be viewed as a function of three things: the exposure of the population to infectious diseases; the population's resistance to these diseases; and once the diseases were contracted, the ability of people to survive their effects. Each of the independent variables in our analysis of mortality variation must operate through one or more of these three factors: exposure, resistance, and case survival.

Several variables had their greatest impacts on mortality levels by influencing the exposure of the population to disease. We hypothesize that density, crowding, and water purity probably affected mortality levels through this route. In addition, migrants to the cities, both foreign-born and from within the country, provided a nonimmune pool for the spread of some diseases. Their presence, therefore, increased the exposure of the native population to these diseases and to new diseases that the migrants brought into cities. Evidence that the mortality rates of non-migrant populations were higher in the presence of large numbers of migrants suggests that the influence of migrants on exposure may have been fairly strong (Higgs, 1979).

If migrants had previously experienced different exposure to diseases than had the nonmigrant population, then inmigration also changed the average level of resistance in the population of the city. For some diseases the effect of prior exposure on resistance was probably negative and for others it may well have been positive.

Another variable which may have affected both resistance and exposure is climate. The numbers of deaths from some diseases were higher in cold climates during the winter, probably because of the decreased resistance of the population. Warm climates, in contrast, provided better breeding grounds for some bacteria and disease-carrying vectors than did cold climates and, therefore, other diseases, especially water- and foodborne diseases, were likely to have been more prevalent in warm climates.

The level of living of a city's population is assumed to have affected mortality rates primarily through its influence on the purchase of health-enhancing goods by individuals, good nutrition being foremost among these. Poor nutrition is recognized as a major determinant of people's resistance to disease and, therefore, probably had a major impact on mortality via that route. Poor nutrition may also have decreased the chances that individuals would survive the diseases they contracted (Chandra, 1979; Martorell, 1980; Suskind, 1977).

The standard of living affected city mortality through a number of routes. First, higher per capita income with a similar distribution of this income would have meant not only better diets for individuals, but also better housing and higher levels of education which should have led to lower mortality. In addition, we recognize that level of living as a general social condition of a city can influence mortality indirectly through its influence at a more aggregate level. For instance, cities with higher levels of living would have more funds available for public expenditures on water purification.

The relationships between a number of the independent variables and the death rates from specific causes of death were examined using regression models. Death rates from tuberculosis, pneumonia, diarrheal diseases, diseases of the nervous system, diseases of the heart, and malaria are included as dependent variables. Tuberculosis and pneumonia, primarily airborne diseases, are especially important in accounting for the variations in adult mortality. Diarrheal diseases, classified as primarily water- and foodborne, constituted an important source of variation in infant mortality. Malaria was included in the analysis for the South because of its importance in explaining mortality variation there and because it is the only identifiable vectorborne disease. Two categories of disease, diseases of the nervous system and diseases of the heart, which were not classified by mode of transmission, are also included for comparison. Diseases of the nervous system accounted for a large part of the variation in infant mortality and included both infectious and noninfectious diseases. Diseases of the heart were probably largely noninfectious but may have contained some infectious components from deaths due to diseases such as rheumatic fever.

Because the etiology of the disease categories used as dependent variables differs, several combinations of independent variables have been proposed to explain the variation in each of these disease categories. Before presenting the regression results, we discuss the operational definitions and the relationships among the independent variables. Pearson correlation coefficients among the independent variables are presented separately for our two regional groups in Table 3.

THE INDEPENDENT VARIABLES

Density and Crowding

Density is measured by the number of persons per acre and the level of density, therefore, depends on the administrative boundaries of a city. This may constitute a problem when these boundaries were not the most relevant for mortality analysis (Meeker, 1970; Higgs and Booth, 1979). Crowding is defined as the number of persons per dwelling unit. In the 1900 census the dwelling unit was often a building rather than a household, and consequently high levels of crowding may have resulted from crowding within households, and/or from large numbers of households per dwelling unit.

Density and crowding were expected to be closely associated with each other; however, as shown in Table 3, the Pearson correlation coefficient between the two variables is insignificant (.16) for northern cities. Across southern cities, density and crowding were strongly positively related (.54).

Water Purity

Death rates from typhoid fever are used as indicators of the purity of water in cities.[4] Dramatic declines in typhoid death rates following improvements in water conditions in a number of cities attest to the very close association between typhoid fever and water conditions (Condran and Cheney, 1982; Sedgwick and MacNutt, 1910). The use of this measure has an advantage over other available measures in that low typhoid fever death rates reflect the existence of clean water, whether from the source or from the provision of sewers and central water systems. Con-

Table 3 Pearson Correlation Coefficients Between Independent Variable: Northern and Western Cities (Above Diagonal)/Southern Cities (Below Diagonal), 1900[1]

	Crowding	Density	Typhoid Rate	% Foreign Born	% Illiterate	Climate	% Black	Growth Rate (1890–1900)	Mean (North)	Mean (South)
Crowding	—	.16	-.25*	.61*	.38*	-.13	-.21*	.03	6.5	5.6
Density	.54*	—	.15	.02	-.08	-.09	-.01	-.07	11.8	14.8
Typhoid Rate	.23	-.26	—	-.40*	-.15	.15	-.28*	.01	36.7	67.9
% Foreign-born	-.17	.06	-.40	—	.62*	-.08	-.48*	.14	24.5	7.7
% Illiterate	-.04	-.26	.26	-.82*	—	.05	-.16	.14	4.7	12.8
Climate	.23	.56*	-.23	.47*	-.74*	—	-.22*	-.34*	116.2	71.5
% Black	.16	-.19	.36	-.88*	.93*	-.59*	—	-.01	2.5	31.6
Growth Rate (1890-1900)	-.11	-.29	-.19	-.15	.32	-.24	.21	—	33.5	21.8

SOURCE: Population–U.S. Census Office, 1902a: Part II, 122-149.
Dwelling Units–U.S. Census Office, 1902a: Part II.
Acres–U.S. Department of Labor, 1900.
Typhoid Death Rate–U.S. Census Office, 1902b: 285-555.
Foreign-born–U.S. Census Office, 1902a: Part I, 796-803.
Percent Illiterate–Meeker, 1970: Appendix A-2.
Climate–U.S. Bureau of the Census, 1975: 186.

NOTES: 1. N = 88 in North and West; N = 15 in South
*Significant at the .05 level or below.

versely, high typhoid death rates are a sign that the water is polluted (Whipple, 1908).

Levels of Living

The variable used to measure levels of living in a city should reflect a population's ability to increase its life chances by purchasing improved nutrition, housing, and education. We use the percentage illiterate in a city's adult population as such a measure. Because the relationship between living levels and mortality is nonlinear, this measure has an advantage over several other available measures of living levels in that it represents proportions at the lower end of the income scale, where the impact of income differentials on mortality should be greatest (Preston, 1976).[5]

The percentage of illiteracy was closely associated with the percentage of foreign-born in northern and western cities and with the percentage of blacks in southern cities (see Table 3). Among the latter, the correlation was so high that the two variables were used interchangeably as measures of living standards in separate equations. For northern cities equations containing both the percentage illiterate and the percentage of foreign-born were specified along with equations containing only the percentage illiterate.

Level of Immigration

The proportion of the population that was foreign-born was included as an indicator of the cumulative level of immigration in northern cities. The foreign-born were poorer than the native white population and lived in more crowded conditions; however, even when these factors were controlled, immigrants were expected to have a direct effect on mortality levels because they were a population that had been exposed to different levels and perhaps strains of diseases during childhood and adolescence.[6] They may have differed from the native population in their exposure and immunity to disease and perhaps even in the level of infection from diseases with long periods of incubation and communicability.

The percentage of foreign-born had a strong association with a number of other independent variables (see Table 3). In northern cities, the percentage foreign-born had a significant positive zero-order correlation with crowding and the percentage illiterate and a significant negative correlation with the typhoid rate. In the South, the percentage foreign-born was very highly negatively correlated with the percentage of blacks and the percentage illiterate. Because of this high level of multicollinearity, the percentage foreign-born is not included in the equations for southern cities.

Level of Inmigration

The growth rate of the city from 1890 to 1900 was used as a measure of recent inmigration. Because the susceptibility of recent migrants to the city to tuberculosis has been given a major role in explaining levels of that disease (Grigg, 1958), we have included the decadel growth rate in equations explaining the variation in tuberculosis rates.

Climate

The average number of days per year during which the temperature falls below freezing is used to indicate climatic conditions. Depending upon the availability of records, averages were based on a varying number of years, ranging from 7 to 59. In the few cases where temperature records were not available for cities in our analysis, the temperature figures for the closest available city were used.

REGRESSION RESULTS

Cause-specific death rates were regressed on selected independent variables separately for northern and western (Table 4) and

Table 4 Regression of Cause-Specific Death Rates Unspecified Variables (per 100,000 Population) (Unstandardized Regression of Coefficients: t-Values in Parentheses)

	Northern and Western Cities N = 88										
Equation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Tuberculosis	Tuberculosis	Pneumonia	Pneumonia	Tuberculosis	Pneumonia	Diarrheal Diseases	Diarrheal Diseases	Diseases of the Nervous System	Diseases of the Nervous System	Diseases of the Heart
Crowding	7.17* (2.26)	5.63* (2.06)	9.80* (3.54)	9.63* (4.06)	9.64* (2.94)	10.22* (3.77)	3.49 (1.53)	5.57* (2.70)	-0.77 (0.26)	-5.15 (1.86)	-1.51 (0.74)
Density	0.65 (0.94)	0.71 (1.04)	2.28* (3.80)	2.29* (3.88)	1.28 (1.73)	1.93* (3.16)	0.60 (1.13)	0.52 (0.96)	2.48* (3.59)	2.64* (3.67)	0.34 (0.74)
Typhoid Fever Rate	**	**	**	**	**	0.55* (2.29)	0.24 (1.20)	0.10 (0.50)	-0.38 (1.46)	-0.10 (0.38)	-0.05 (0.29)
% Foreign-born	-0.77 (0.95)	**	-0.09 (0.13)	**	-1.97* (2.14)	0.48 (0.66)	1.27 (1.98)	**	-2.68* (3.23)	**	0.05 (0.28)
% Illiterate	2.53 (0.88)	1.41 (0.54)	8.35* (3.41)	8.22* (3.75)	2.75 (0.89)	7.29* (3.00)	14.06* (6.86)	15.72* (8.27)	12.19* (4.58)	8.68* (3.39)	-0.17 (0.09)
Climate	-0.33* (2.06)	-0.32* (2.00)	0.10 (0.71)	0.10 (0.77)	-0.20 (1.05)	0.04 (0.31)	0.09 (0.75)	0.09 (0.75)	0.21 (1.40)	0.22 (1.38)	-0.32* (3.20)
Growth Rate (1890-1900)	-0.36 (1.29)	-0.37 (1.32)	**	**	-0.45 (1.61)	**	**	**	**	**	**
Age Control***	4.56* (2.09)	4.71* (2.17)	0.99 (0.53)	1.00 (0.54)	2.43 (1.06)	0.31 (0.17)	0.78 (0.38)	1.59 (0.78)	-2.41 (0.91)	-4.13 (1.51)	-1.79 (1.28)
New England Region	**	**	**	**	38.25* (2.28)	**	**	**	**	**	**
Western Region	**	**	**	**	50.35 (1.82)	**	**	**	**	**	**
Central Region	**	**	**	**	5.80 (0.40)	**	**	**	**	**	**
constant	-56.59	-69.42	-14.15	-15.60	31.54	0.70	-33.70	-33.74	243.72	243.81	272.08
R^2	.21	.20	.48	.48	.27	.51	.65	.63	.31	.22	.14
R^2	.14	.14	.44	.45	.18	.47	.62	.61	.25	.16	.06
F	3.00	3.35	12.47	15.15	2.86	12.01	21.37	23.45	5.04	3.73	1.80

NOTE: *Significant at .05 level or below

**Not included in equation

***Age control variables are for tuberculosis, pneumonia, and diseases of the heart, the proportion of the population aged 20-55; for diarrheal diseases and diseases of the nervous system, the proportion of the the population aged 0-9.

SOURCE: Mortality Rates–Same as Table 1; Independent Variables–Same as Table 3.

for southern cities (Table 5).[7] Data for all the independent variables are available for 88 northern and western cities and 15 southern cities.[8] Because the number of cities in the South is small, the results for the South must be interpreted with some caution.

Tuberculosis and Pneumonia

We hypothesized that the levels of mortality from tuberculosis and pneumonia, both primarily airborne diseases, were affected by most of the independent variables listed above. For northern cities equations including crowding, density, the percentage foreign-born, the percentage illiterate, climate, and an age-control variable are specified for both disease categories. In addition, because of the high correlation between the percentage foreign-born and the percentage illiterate, equations containing only the percentage illiterate are also presented (see Table 4, equations 2 and 4). Both the overall density of a city and the crowding of persons within households or dwelling units were hypothesized to have been positively related to tuberculosis and pneumonia death rates. Both density and crowding were likely to have increased the number of contacts between people, and hence to have aided in the spread of airborne infectious diseases.

The percentage illiterate and the percentage foreign-born were expected to have been positively related to these diseases. The latter was expected to have had a stronger relationship to the tuberculosis death rates than to the pneumonia death rates, because exposure to tuberculosis may have provided long-term immunities to the disease. Consequently, the introduction of potentially unexposed persons as measured by the percentage foreign-born should have had a greater impact on the levels of tuberculosis than on the levels of pneumonia. The growth rate of the city was hypothesized to have affected the tuberculosis rate, because rural populations moving into the cities were likely to have less exposure to and, therefore, less immunity to tuberculosis. No such effect was considered likely in the case of

Table 5 Regression of Cause-Specific Death Rates Unspecified Variables (per 100,000 Populations) (Unstandardized Regression Coefficients: t-Values in Parentheses)

	Southern Cities N = 15									
Equation	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
	Tuberculosis	**Tuberculosis**	**Pneumonia**	**Pneumonia**	**Diarrheal Diseases**	**Diarrheal Diseases**	**Diseases of the Nervous System**	**Diseases of the Nervous System**	**Diseases of the Heart**	**Malaria**
Crowding	-25.61 (1.03)	21.57 (0.80)	-11.20 (0.21)	17.36 (0.36)	22.93 (0.54)	57.17 (1.12)	-76.58 (1.24)	-66.89 (1.10)	-36.54 (1.08)	**
Density	0.93 (0.61)	-1.34 (0.71)	-1.37 (0.43)	-2.93 (0.86)	0.98 (0.37)	0.55 (0.16)	8.42 (2.18)	8.58 (2.10)	3.39 (1.47)	-0.96 (0.33)
Typhoid Fever Rate	**	**	**	**	1.23 (2.17)	1.37 (1.96)	1.54 (1.87)	1.59 (1.92)	0.55 (1.02)	**
% Black	4.32* (5.48)	**	2.69 (1.65)	**	3.42* (3.00)	**	0.97 (0.58)	**	0.52 (0.45)	2.96* (2.41)
% Illiterate	**	14.41* (4.45)	**	10.41 (1.78)	**	7.96 (1.72)	**	1.12 (0.20)	**	**
Climate	-0.80 (1.70)	-0.15 (0.22)	0.75 (0.77)	1.44 (1.17)	-0.02 (0.03)	-0.18 (0.16)	-1.37 (1.23)	-1.63 (1.25)	-0.99 (1.59)	-0.03 (0.03)
Growth Rate (1890-1900)	-2.29* (3.51)	-3.06* (4.16)	**	**	**	**	**	**	**	**
Age Control***	-3.32 (0.59)	-0.54 (0.08)	0.07 (0.01)	-1.43 (0.14)	30.01 (2.08)	18.90 (1.13)	-8.35 (0.40)	-13.22 (0.66)	1.52 (0.21)	**
constant	591.12	133.64	162.98	6.96	-710.35	-694.55	732.34	799.83	273.13	-13.57
R^2	.94	.92	.38	.40	.83	0.74	0.58	0.57	0.59	0.48
R^2	.90	.86	.03	.06	.71	0.55	0.27	0.24	0.28	0.34
F	20.98	15.00	1.08	1.19	6.74	3.87	1.87	1.76	1.92	3.37

NOTE: *Significant at .05 level or below
**Not included in equation
***Age control same as on Table 4.

SOURCE: Same as Table 4

pneumonia. Therefore, the decadal rate of population growth was used in equations explaining the variance in tuberculosis death rates, but not the pneumonia death rates.

Examination of Table 4 (equations 1-4) shows that in northern cities, both density and crowding had a statistically significant effect in the expected direction on pneumonia death rates. Crowding was also significant in explaining the variance in tuberculosis rates, but density was not. An increase of one person per dwelling unit in a city's crowding levels would have lead to an increase of ten deaths from pneumonia and six to ten deaths from tuberculosis per 100,000 persons. Increasing density per acre by one person would lead to an increase of two deaths from pneumonia per 100,000 persons.

Table 4 indicates several other relationships. The percentage illiterate was strongly related to pneumonia death rates. The climate variable was insignificant in the pneumonia equations and significantly related in the unexpected direction with the tuberculosis death rates. The regression equations were less successful in explaining the variance in tuberculosis death rates (adjusted $R^2 = .14$) than in the pneumonia death rates (adjusted $R^2 = .44$ or $.45$). An important difference between tuberculosis and pneumonia, which may have contributed to the wide disparity in R^2 values for the two diseases, is that people who contracted tuberculosis often suffered from the disease for many years before they died from it. Therefore, especially in relatively mobile urban populations, tuberculosis may have been less related to time-specific local environmental conditions than pneumonia.

Another interpretation of the low adjusted R^2 value in the tuberculosis equations arises from an examination of time-series data on tuberculosis mortality for individual cities throughout the nineteenth century. Other research has shown in most cities that tuberculosis mortality rates rose to a peak and then declined, and that the timing of the peak varied from region to regions. In general, the farther west a northern city was from the Atlantic seaboard, the later the date of the peak. Atlantic seacoast cities peaked around 1800. Cities in a 500-mile radius around Chicago experienced peak tuberculosis mortality in 1860. The far-western peak occurred just prior to 1910 (Grigg, 1958).

In an attempt to test the effect of regional location, a dummy variable for region is included among the independent variables affecting tuberculosis (see Table 4, equation 5). The results indicate that for these cities only cities in New England had significantly higher tuberculosis mortality than cities in the Middle Atlantic region, which is the omitted category. While western cities in the sample did have the highest tuberculosis death rates, the difference between the coefficient for this region and others was not statistically significant. Since these results are based on a cross-section of cities, they do not prove or disprove the hypothesis about the time trend in tuberculosis mortality by region. They do, however, suggest some regional differences in tuberculosis rates. The inclusion of region results in a stronger relationship between a city's tuberculosis death rate and crowding and a significant negative relationship between tuberculosis death rates and the percentage foreign-born. In addition, when region is controlled, the unexplained negative relationship between tuberculosis and climate found in equations 1 and 2 disappears.

Finally, for northern cities, the typhoid fever death rate was added to the pneumonia equation (see Table 4, equation 6). Pneumonia was, of course, not generally transmitted by impure water. However, when water in individual cities was purified at the end of the nineteenth and the beginning of the twentieth centuries, health officials noted that deaths from diseases that were not waterborne diseases also declined. Called the Mills-Reincke phenomenon, the ratio between changes in mortality from all causes and that from typhoid fever was estimated to be as high as 15.8 in some cities (Sedgwick and MacNutt, 1910). We have, therefore, included the typhoid fever death rate in the pneumonia equation to determine its effect in the cross-section on a disease that was not waterborne. The typhoid fever death rate does have a significant positive effect on the death rate from pneumonia, and, therefore, supports the notion that pure water affected other than waterborne diseases. In the northern and western cities, a decrease of one death per 100,000 population from typhoid fever was accompanied by a decrease of .55 deaths from pneumonia. Our finding only supports and does not confirm the existence of the Mills-Reincke phenomenon, because it is based on variation at one point in time rather than over time.

In contrast to the North and West, we are much more successful in explaining the variance in tuberculosis than in pneumonia death rates in the South (see Table 5, equations 1-4). The proportion of the population which was black is the key variable explaining the variation in southern urban death rates from tuberculosis. We expected the percentage black to be related to mortality levels in southern cities primarily because it is an indicator of the relative size of a group living in the worst conditions in each of these cities. The percentage illiterate has a similar effect on the R^2 when it replaces the percentage black in the equation. Neither the percentage black nor the percentage illiterate is significant in explaining pneumonia death rates in the southern cities. Our results for southern cities differ markedly from those for northern and western cities where the measure of living level was highly related to pneumonia death rates but unrelated to tuberculosis death rates.

Diarrheal Diseases

The equations for diarrheal diseases contain all the variables previously used in explaining pneumonia, including the death rate from typhoid fever, used as a measure of clean water. Although we classified diarrheal diseases as transmitted by impure water and food, the typhoid fever death rate was not significant in explaining the variation in this disease category in northern and western cities (see Table 4, equations 7 and 8). Death rates from diarrheal diseases were, however, significantly positively related to the percentage illiterate in cities. When the percentage foreign-born was not included in the equation, crowding became important in explaining the variation in city death rates from diarrheal diseases. The relationship between death rates and each of these variables—crowding and the percentage illiterate—probably reflects the relationship between socieoeconomic status and mortality from diarrheal diseases especially among children. For children who are well-nourished, diarrhea is generally not a serious disease; however, for poorly nourished children it can be quite deadly (Scrimshaw et al., 1968).

The percentage of blacks is strongly positively related to diarrheal diseases in the equation for southern cities; however, the percentage illiterate was not significant (see Table 5, equation 5 and 6). As in the North and West, the expected positive relationship between the measure of water purity and diarrheal death rates does not appear in this equation.

Diseases of the Nervous System and Heart Disease

These two disease categories included in Tables 4 (equations 9, 10, and 11) and 5 (equations 7, 8, and 9) contained a number of noninfectious diseases. We expected the framework to be less effective in explaining the variation in the death rates from these disease categories than when applied to largely infectious diseases. In northern cities, the percentage illiterate and density were both positively significantly related to nervous system death rates. Cities with higher percentages of their population foreign-born had lower death rates from these diseases. Largely due to these variables, we were able to explain 25% of the variation in diseases of the nervous system, which contained a combination of infectious and noninfectious diseases. The explanatory power of this equation was substantially below those explaining the pneumonia and diarrheal death rates. Only 6% of the variation in diseases of the heart was explained by an equation containing all the variables in the model. This percentage was far below those for any of the categories containing primarily infectious diseases.

For southern cities, the variation explained in diseases of the heart was about the same as that of diseases of the nervous system. The R^2 values for both, however, were far below those for tuberculosis and diarrheal diseases but well above the very low pneumonia value.

Malaria

Malaria death rates are regressed on three independent variables for southern cities (see Table 5, equation 10). Cities with higher densities and colder climates were hypothesized to have lower levels of malarial mortality. The percentage of blacks was expected to be negatively related to death rates from malarial mortality because the black population is assumed to have had greater immunity to malaria than the white population. None of these hypotheses was supported by the data. In fact, the percentage of blacks in the population was strongly positively related to the malarial death rate, probably because the black population lived in areas and homes where there was more exposure to malaria.

SUMMARY

The significance of analyzing death rates by cause is apparent from our results. In northern and western cities diarrheal diseases had a strong negative relationship to indicators of the socio-economic levels of city populations. Death rates from pneumonia were also higher where city living levels were lower but, in addition, they were higher where the number of possible contacts was greater and the water was not pure. Death rates from tuberculosis were higher in crowded cities and in New England, and were lower in cities with a higher percentage of foreign-born. The amount of the variation explained by the models differed from one cause of death to another. For northern and western cities, we were able to explain only 18% of the variation in death rates from tuberculosis, compared to 62% of the variation in diarrheal diseases.

The results for southern cities are based on so few cities that they are merely suggestive. Only for two diseases—tuberculosis and diarrheal disease—is a significant amount of the variation in city death rates explained and in each case, the important explanatory variable was the percentage black.

CONCLUSIONS

A two-stage analysis has provided interesting insight into the factors underlying the variation in the mortality levels of cities in 1900. In the first stage, we isolated the causes of death accounting for the differential mortality levels in the crude death rate and for mortality among infants and young adults. We found that a few specific causes of death accounted for large proportions of the variation in city death rates. The importance of causes of death in explaining variation in city death rates differed for infants and adults.

In the second stage of our analysis, a general framework explaining variation in death rates from infectious diseases was outlined, and regression equations were specified for several causes of death isolated as important determinants of variation in mortality levels for the different age groups in stage one. Different equations were estimated for causes of death having different modes of transmission, and for cities in the two regional groups. Our results varied from disease to disease. Individual independent variables were only important in explaining some causes-of-death categories. In addition, the models specified were more successful in explaining the variation in some disease categories than in others.

It is apparent from our work that no simple answers explain why mortality levels differed, either in terms of the causes of death accounting for the variation or in terms of the factors influencing the levels of cause-specific mortality. Mortality differentials, whether cross-sectional or overtime, come as a result of complex sets of circumstances requiring not only a multivariate research design, but one that takes account of the fact that different specifications of the model are needed for different causes of death.

APPENDIX

Albany, NY
Allegheny, PA*
Allentown, PA
Altoona, PA
Atlanta, GA
Atlantic City, NJ**
Auburn, NY
Baltimore, MD
Bay City, MI**
Bayonne, NJ**
Binghamton, NY
Boston, MA*
Bridgeport, CT
Brockton, MA
Buffalo, NY*
Cambridge, MA
Camden, NJ
Canton, OH
Charleston, SC
Chelsea, MA
Chicago, IL*
Cincinnati, OH*
Cleveland, OH*
Columbus, OH*
Covington, KY
Davenport, IA
Dayton, OH
Denver, CO*
Detroit, MI*
Duluth, MN**
Easton, PA**
Elizabeh, NJ
Elmira, NY
Erie, PA
Evansville, IN
Fall River, MA*
Fitchburg, MA**
Gloucester, MA**
Grand Rapids, MI
Harrisburg, PA
Hartford, CT
Haverhill, MA
Hoboken, NJ
Holyoke, MA
Indianapolis, IN*
Jackson, MI**
Jacksonville, FL**
Jersey City, NJ*
Johnstown, PA
Kansas City, MO*
Lancaster, PA
Lawrence, MA
Lincoln, NE
Los Angeles, CA*
Louisville, KY
Lowell, MA
Lynn, MA
McKeesport, PA
Malden, MA
Manchester, NH
Memphis, TN
Milwaukee, WI*
Minneapolis, MN*
Mobile, AL
Nashville, TN
Newark, NJ
New Bedford, MA
New Britaintown, CT**
New Castle, PA**
New Haventown, CT*
New Orleans, LA
Newport, KY**
Newton, MA**
Bronx & Manhattan, NY*
Norfolk, VA
Oakland, CA
Omaha, NE*
Passaic, NJ**
Patterson, NJ*
Pawtucket, RI
Philadelphia, PA*
Pittsburgh, PA*
Portland, ME
Portland, OR
Providence, RI*
Quincy, IL
Reading, PA
Richmond, VA
Rochester, NY*
Sacramento, CA**
Saginaw, MI
St. Joseph, MO**
St. Louis, MO*
St. Paul, MI
Salem, MA
Salt Lake City, UT
San Antonio, TX**
San Francisco, CA*
Savannah, GA
Schenectady, NY**
Scranton, PA*
Seattle, WA
Sioux City, IA**
Sommerville, MA**
Spokane, WA**
Springfield, IL
Springfield, MA
Superior, WI**
Syracuse, NY*
Tacoma, WA
Taunton, MA
Terre Haute, IN
Toledo, OH*
Trenton, NJ
Troy, NY
Utica, NY
District of Columbia
Waterbury, CT
Wheeling, WV
Wilkesbarre, PA
Williamsport, PA
Wilmington, DE
Woonsocket, RI
Worcester, MA*
Yonkers, NY
Youngstown, OH**

*Included in Table 2
**Eliminated from regression analysis in Tables 4 and 5, because of missing data on independent variables.

NOTES

1. The classification of causes of death used in this research has been largely dictated by the availability of data. Diarrheal diseases included the following categories: cholera morbus, colitis, diarrhea, dysentery, enteritis, and cholera infantum.

2. Diseases of the urinary system is a category of diseases that includes nephritis, Bright's disease, diseases of the bladder and urinary tract, and nonvenereal diseases of the male and female genital organs. This category, therefore, probably included some infectious diseases. The category diseases of the nervous system included convulsions, which, especially among infants, may well have been the result of high fever from infectious diseases.

3. If total mortality rates per 1000 population are regressed on a number of cause-specific death rates that add to the total death rate, the b's sum to 1000 and are the best estimate of the proportion of the variation in total mortality rates explained by each cause of death (Preston, 1976: 19).

4. A variety of measures of the provision of sewers and central water works in cities around the turn of the century have been used to measure environmental quality in previous research. Meeker (1970) used a dummy variable that indicated whether the water was pure or not and measured the provision of sewerage by the number of sewer connections per dwelling in 1890 and a dummy variable indicating the presence or absence of sanitary sewers in 1900. Meeker concluded that these variables did not adequately measure sanitary conditions. In our own previous research (Condran and Crimmins-Gardner, 1978), the amounts spent on the construction of waterworks up to 1900 and the yearly maintenance expenditures on waterworks were negatively related to the adult and typhoid mortality rates, while yearly expenditures on sewers were not significantly related to either age- or cause-specific death rates. From this analysis, we concluded that our measures were not satisfactory indicators of the prevailing sanitary conditions. Expenditures on central water systems may have led to the transport of contaminated water throughout cities. In addition, if cities with higher mortality rates responded to these high rates by installing sewers and waterworks, a positive relationship between mortality levels and public health facilities might be expected in the cross-section. Higgs and Booth (1979) have used typhoid fever death rates as a measure of water purity and we have followed their lead in using this measure. Whipple, the expert on typhoid fever at the beginning of this century, noted the close association between the death rate from this disease and the cleanliness of water (Whipple, 1908).

5. Other available measures were the percentage of homes in the city which were owned, the percentage unemployed, the average male manufacturing wages, and the percentage of those with occupations in each of the following occupational categories: agricultural pursuits, professional services, domestic and personal services, laborers, trade and transportation, and manufacturing and mechanical pursuits. The zero-order correlations between these measures were not very high and were, in fact, often in an unexpected direction. They were, therefore, obviously not all measuring the levels of living in cities or at least were not measuring the same aspect of levels of living. These variables were eliminated from the analysis for a variety of reasons. The percentage unemployed was available for fewer than half of the northern and western cities in our analysis. Male manufacturing wage earners were only a small proportion of the labor force in many cities, and in fact, the higher the average male manufacturing wages, the lower the proportion of the labor force earning these wages. Finally, some of the variables representing the

proportional occupational distributions were probably better indicators of the functional types of cities at the end of the nineteenth century than of levels of living. Because levels of living may have affected mortality through housing, the percentage of housing units that were owner-occupied might have been expected to reflect at least one aspect of the variable we were trying to measure. Available evidence on home ownership in the nineteenth and early twentieth centuries suggests that topography, geography, the nature of the building industry, the behavior of individual developers and entrepreneurs and, of course, the price of land were all shaping the housing market in individual cities. These, in turn, may have had little or no relationship to individual income levels. Some differences in city mortality levels may well be explained by differences in the housing aspect of levels of living, but these housing conditions may be reflecting some general environmental conditions rather than individuals' income levels and expenditures.

6. Using these data we cannot address the question of the relative level of native- and foreign-born mortality in these cities. Registration data permitting the comparison of the mortality of the foreign-born and native population in registration cities were published in the 1900 census. These showed lower age-specific mortality rates for immigrants than for the native white population (U.S. Census Office, 1902b, 1902c). Death rates were calculated for two groups of cities, one containing all registration states. That other group excluded southern and western cities and, therefore, was less affected by the possible regional influence on the comparison. In both groups of cities, the mortality rates of the foreign-born were lower in most age categories than were the rates of the native population. It is possible that even though the mortality of the foreign-born in each city exceeded that of the native-born, the mortality of the foreign-born aggregated over all cities was less than that of the native-born because the foreign-born were concentrated in cities that, for some reason, had low mortality. Higgs and Booth (1979), in an analysis of 17 cities, demonstrated that within individual cities the average ward death rates of the foreign-born consistently exceeded those of the native-born population.

7. Use of the Chow test indicated that regression equations for the group of northern and western cities differed from those for southern for the following diseases: pneumonia, diarrheal diseases, and diseases of the nervous system. For consistency all regressions were run separately for the two groups; one consisting of northern and western cities, the other of southern cities.

8. A comparison of the data in Table 1 with a similar table constructed only for the cities included in the regression equation showed no substantial differences between the two groups of cities in the causes of death accounting for variation in mortality. Among the causes included in the regression analysis, the largest difference between the two tables occurred in the contribution of tuberculosis to the variation in the total mortality rate. It accounted for 10.6% of the variation in the northern and western cities included in the regression, and 12.4% in all 108 northern and western cities.

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