Special Communication

The Association Between Income and Life Expectancy in the United States, 2001-2014

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IMPORTANCE The relationship between income and life expectancy is well established but remains poorly understood.

OBJECTIVES To measure the level, time trend, and geographic variability in the association between income and life expectancy and to identify factors related to small area variation.

DESIGN AND SETTING Income data for the US population were obtained from 1.4 billion deidentified tax records between 1999 and 2014. Mortality data were obtained from Social Security Administration death records. These data were used to estimate race- and ethnicity-adjusted life expectancy at 40 years of age by household income percentile, sex, and geographic area, and to evaluate factors associated with differences in life expectancy.

EXPOSURE Pretax household earnings as a measure of income.

MAIN OUTCOMES AND MEASURES Relationship between income and life expectancy; trends in life expectancy by income group; geographic variation in life expectancy levels and trends by income group; and factors associated with differences in life expectancy across areas.

RESULTS The sample consisted of 1 408 287 218 person-year observations for individuals aged 40 to 76 years (mean age, 53.0 years; median household earnings among working individuals, $61 175 per year). There were 4 114 380 deaths among men (mortality rate, 596.3 per 100 000) and 2 694 808 deaths among women (mortality rate, 375.1 per 100 000). The analysis yielded 4 results. First, higher income was associated with greater longevity throughout the income distribution. The gap in life expectancy between the richest 1% and poorest 1% of individuals was 14.6 years (95% CI, 14.4 to 14.8 years) for men and 10.1 years (95% CI, 9.9 to 10.3 years) for women. Second, inequality in life expectancy increased over time. Between 2001 and 2014, life expectancy increased by 2.34 years for men and 2.91 years for women in the top 5% of the income distribution, but by only 0.32 years for men and 0.04 years for women in the bottom 5% ($P < .001$ for the differences for both sexes). Third, life expectancy for low-income individuals varied substantially across local areas. In the bottom income quartile, life expectancy differed by approximately 4.5 years between areas with the highest and lowest longevity. Changes in life expectancy between 2001 and 2014 ranged from gains of more than 4 years to losses of more than 2 years across areas. Fourth, geographic differences in life expectancy for individuals in the lowest income quartile were significantly correlated with health behaviors such as smoking ($r = −0.69$, $P < .001$), but were not significantly correlated with access to medical care, physical environmental factors, income inequality, or labor market conditions. Life expectancy for low-income individuals was positively correlated with the local area fraction of immigrants ($r = 0.72$, $P < .001$), fraction of college graduates ($r = 0.42$, $P < .001$), and government expenditures ($r = 0.57$, $P < .001$).

CONCLUSIONS AND RELEVANCE In the United States between 2001 and 2014, higher income was associated with greater longevity, and differences in life expectancy across income groups increased over time. However, the association between life expectancy and income varied substantially across areas; differences in longevity across income groups decreased in some areas and increased in others. The differences in life expectancy were correlated with health behaviors and local area characteristics.

JAMA. doi:10.1001/jama.2016.4226
Published online April 10, 2016.

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Higher incomes are associated with longer life expectancy,[1-9] but several aspects of the relationship between income and longevity remain unclear. First, little is known about the exact shape of the income-longevity gradient. Is there a threshold above which additional income is no longer associated with increased life expectancy or a safety net below which further reductions in income do not harm health?

Second, there is debate about how socioeconomic gaps in longevity are changing over time. Prior work has shown that longevity gaps increased in recent decades. Some studies suggest a reduction in life expectancy for women of low socioeconomic status in recent years, but this conclusion has been questioned.[6,10-14]

Third, most studies have examined the relationship between income and longevity at a national level. To what extent do gaps in longevity vary at the local area level?

Fourth, the sources of the longevity gap remain unclear. The socioeconomic gradient in longevity has been variously attributed to factors such as inequality, economic and social stress, and differences in access to medical care.[15] These theories remain debated.

This study addressed these 4 issues by analyzing newly available data on income and mortality for the US population from 1999 through 2014. The following sets of analyses were conducted: (1) characterizing the association between life expectancy at 40 years of age and income in the United States as a whole; (2) estimating the change in life expectancy by income group from 2001 through 2014; (3) mapping geographic variation in life expectancy by income group and over time; and (4) evaluating factors associated with differences in longevity using the variation across areas.

SSA *Social Security Administration*

NCHS *National Center for Health Statistics*

NLMS *National Longitudinal Mortality Study*

Methods

This study was approved by the Office of Tax Analysis of the US Treasury under Internal Revenue Code §6103(h)(1). Institutional review board approval was obtained through the Harvard University Committee on the Use of Human Subjects; participant consent was waived because the analysis used preexisting, deidentified data. The analysis used a deidentified database of federal income tax and Social Security records that includes all individuals with a valid Social Security Number between 1999 and 2014.

Income data were obtained from tax records for every individual for every year from 1999 through 2014. The primary measure of income was pretax household earnings. For those who filed tax returns, household earnings were defined as adjusted gross income plus tax-exempt interest income minus taxable Social Security and disability benefits. For those who did not file a tax return, household earnings were defined as the sum of all wage earnings (reported on form W-2) and unemployment benefits (reported on form 1099-G). When individuals had no tax return and no information returns, household earnings were $0. For nonfilers, earnings did not include the spouse's income. However, the vast majority of nonfilers who are not receiving Social Security benefits are single.[16] Income was adjusted to 2012 dollars using the consumer price index.

Mortality was measured using Social Security Administration (SSA) death records. Total deaths in the SSA data closely match data from the National Center for Health Statistics (NCHS), with correlations exceeding 0.98 across ages and years (part I of the eAppendix, eFigure 1, and eTable 1 in the Supplement). Observations with income of $0 were excluded because the SSA does not fully track deaths of nonresidents, and thus mortality rates for individuals with income of $0 are mismeasured or unavailable. After excluding observations with income of $0, individuals were assigned percentile ranks from 1 to 100 based on their household earnings relative to all other individuals of the same sex and age in the United States during each year.

National Levels of Life Expectancy by Income

The study estimated period life expectancy, which was defined as the expected length of life for a hypothetical individual who experiences mortality rates at each subsequent age that match those in the cross-section during a given year. Period life expectancy conditional on income percentile at 40 years of age (or equivalently, expected age at death, calculated as life expectancy plus 40 years), was constructed by (1) estimating mortality rates for the ages of 40 to 76 years; (2) extrapolating mortality rates beyond the age of 76 years and calculating life expectancy; and (3) adjusting for differences in the proportion of racial and ethnic groups across percentiles. A complete description of these 3 steps appears in part II of the eAppendix in the Supplement. The entire analysis was conducted separately for men and women.

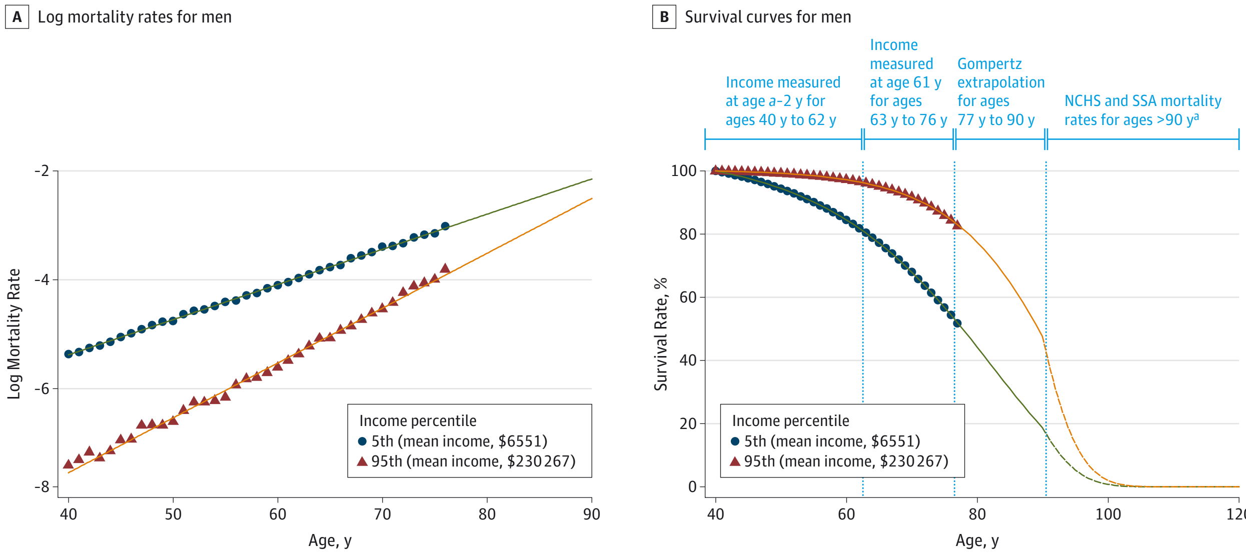
For individuals aged 63 years or younger, mortality rates were calculated based on income percentile 2 years earlier. The 2-year lag helps mitigate reverse causality arising from income changes near death.[9] Because of this 2-year lag, mortality rates were available from 2001 through 2014. Mortality rates conditional on income percentile 2 years prior are approximately equivalent to mortality rates conditional on income percentile at the age of 40 years because individuals' earnings are highly correlated over time between the ages of 40 years and 61 years (eFigure 2 and eTable 2 in the Supplement).

Earnings after the age of 61 years are less highly correlated with earnings at earlier ages because the rate of retirement increases sharply at 62 years of age, the earliest age of eligibility for Social Security benefits.[17] Therefore, income for individuals aged 63 years or older was measured at 61 years of age. Because 1999 is the earliest year in which income was observed and the mortality data end in 2014, mortality rates were calculated up to 76 years of age.

Beyond the age of 76 years, mortality rates were estimated using Gompertz models, in which mortality rates increase exponentially with age.[18,19] In a Gompertz model, the logarithm of the mortality rate is linear in age: $\log(m(age)) = \alpha + \beta age$. This log-linear approximation fits NCHS data for mortality rates above 40 years of age with R^2 values of greater than 0.99 for both sexes (eFigure 3 in the Supplement). The log-linear approximation also fits mortality rates at specific income percentiles well (for example, $R^2 > 0.99$ at the 5th and 95th percentiles; **Figure 1**A and eFigure 4).

The Gompertz parameters α (representing the intercept of the Gompertz model) and β (representing the slope) were estimated for

Figure 1. Gompertz Approximations and Empirical Survival Curves for Men in the 5th and 95th Income Percentiles, 2001-2014



For panels A and B, the data for the scatter points were derived from cross-sectional mortality rates by age using income 2 years prior for men aged 40 to 62 years and cohort mortality rates by year using income observed at age 61 years for men aged 63 to 76 years. Empirical mortality rates were observed until the age of 76 years; therefore, empirical survival rates are observed until the age of 77 years. Solid lines show Gompertz extrapolations through the age of 90 years. In panel B, uniform mortality rates from the National Center for Health Statistics (NCHS) and the Social Security Administration (SSA) were used beyond the age of 90 years. Analogous results for women appear in eFigure 4 in the Supplement.

[a] The mortality rates were constant across income groups.

each sex, income percentile, and year using maximum likelihood, modeling deaths at each age using a binomial distribution. When pooling all years, mortality rates up to the age of 76 years were used to estimate α and β. When computing year-specific estimates, α and β were estimated using data up to the age of 63 years, so that all years were treated symmetrically. Because the Gompertz model fits less well after the age of 90 years, all survivors at the age of 90 years were assigned sex-specific but income-independent mortality rates based on NCHS and SSA data.[20-22] The mortality rate estimates were used to construct survival curves for each income percentile (Figure 1B), and life expectancy was calculated as the area under the survival curve.

The life expectancy estimates were adjusted to control for differences in the racial and ethnic composition of income groups in 2 steps. Data from the National Longitudinal Mortality Study (NLMS) were used first to estimate mortality rates by age for black, Hispanic, and Asian individuals, relative to all other groups using Gompertz models controlling for differences in income (eFigure 5 in the Supplement). Log differences in mortality rates across races at a given age were assumed to be constant across income groups and areas, an approximation consistent with the NLMS data (eFigures 6 and 7). US Census data were then used to estimate the share of black, Hispanic, and Asian individuals in each income percentile by sex, age, and year. These data were combined to calculate the mean life expectancy that would prevail if each group had proportions of black, Hispanic, and Asian individuals corresponding to national means at the age of 40 years. In both the NLMS and the US Census, race and ethnicity are reported by individuals based on fixed categories (non-Hispanic black, non-Hispanic Asian, Hispanic or Latino of any race).

National Trends in Life Expectancy by Income

Year-specific estimates of life expectancy were constructed by income quartile and ventile (5 percentile bins) to reduce estimation error. Trends in life expectancy were estimated using linear regressions of race- and ethnicity-adjusted life expectancy in each quartile or ventile on year.

Local Area Variation in Life Expectancy by Income

Individuals' locations were defined based on the zip code from which they filed tax returns or, for nonfilers, where their W-2 forms were mailed during the year their income was measured. Those individuals who moved after the age of 63 years (ie, after retirement age) were therefore classified as belonging to the location where they lived at the age of 61 years (where they worked).

The level of race- and ethnicity-adjusted life expectancy was estimated by income quartile and ventile for counties, commuting zones, and states, pooling data from 2001 through 2014. Commuting zones are geographic aggregations of counties based on commuting patterns in the 1990 US Census that are widely used as measures of local labor markets. There are 741 commuting zones in the United States compared with more than 3000 counties and more than 40 000 zip codes. The results reported are primarily for commuting zones because these zones constitute broad geographic units analogous to metropolitan statistical areas. However, unlike metropolitan statistical areas, commuting zones provide a complete partition of the country, including rural areas.

The amount of variation in life expectancy across areas was measured as the standard deviation of life expectancy across areas (weighted by population in the 2000 US Census) after subtracting the variance across areas due to sampling error. Trends were estimated by regressions of year-specific race- and ethnicity-adjusted life expectancy estimates on calendar year separately in each area. Trend estimates were constructed by income quartile for the 100 most populated commuting zones (with populations >590 000) and for states.

Correlates of Local Area Variation in Life Expectancy

Theories for differences in life expectancy were evaluated by correlating commuting zone–level estimates of race- and ethnicity-adjusted life expectancy for individuals in the bottom and top income quartiles with local area characteristics. Detailed definitions of these characteristics and sources appear in part III of the eAppendix and in eTable 3 in the Supplement.

Health behaviors were measured by income quartile using the Behavioral Risk Factor Surveillance Surveys from 1996 through 2008. The health behaviors included were rates of current smoking, obesity (defined as body mass index [calculated as weight in kilograms divided by height in meters squared] ≥30), and self-reported exercise during the past month.

Measures of access to medical care included the fraction uninsured, risk-adjusted Medicare spending per enrollee, an index for the quality of inpatient care based on 30-day hospital mortality rates, and an index for the quality of primary and preventive care based on the fraction of people who visited primary care physicians and received routine care, such as mammograms, constructed using Medicare claims data.[23]

Residential income segregation was measured using the Reardon rank order index; higher numbers indicate greater segregation.[24] Income inequality was estimated with the Gini index using tax records; higher numbers indicate a more unequal income distribution. Social cohesion was estimated using a social capital index based on the methods of Putnam[25] and the share of the population that is religious. The percentage of black individuals was measured in the 2000 US Census.

The following measures of local labor market conditions were used as proxies for the strength of local economies: the unemployment rate in 2000, population change between 1980 and 2000, and labor force change between 1980 and 2000.

Several other correlates were constructed using US Census data and other sources, for example, population density, the fraction of college graduates, and median home values (a complete list appears in eTable 3 in the Supplement).[26]

Data Analysis and Availability

The raw data were collapsed into means by sex, age, income, year, and geographic area using SAS version 9.1.3 (SAS Institute Inc). The means by sex, age, income, year, and geographic area were analyzed using Stata version 13 (StataCorp). Tests of statistical significance were based on 2-sided tests with a significance threshold of .05. The 95% confidence intervals for the race- and ethnicity-adjusted life expectancy estimates were calculated using a bootstrap resampling procedure (part II.E of the eAppendix in the Supplement). Correlation coefficients were calculated using Pearson correlation measures, weighted by population. Data sets containing life expectancy estimates by age, sex, year, and income group at the national, state, commuting zone, and county level are available at www.healthinequality.org.

Results

The sample consisted of 1 408 287 218 person-year observations for individuals aged 40 to 76 years from 1999 through 2014. The mean age at which people were analyzed was 53.0 years. Among individuals of working age (38-61 years), the median for household earnings was $61 175 per year and the mean for household earnings was $97 725 per year. There were 4 114 380 deaths from the SSA death files among men (mortality rate of 596.3 per 100 000) and 2 694 808 deaths among women (mortality rate of 375.1 per 100 000).

National Levels of Life Expectancy by Income

Figure 2 shows race- and ethnicity-adjusted expected age at death by household income percentile using pooled data from 2001 through 2014. Higher income was associated with longer life throughout the income distribution. Men in the bottom 1% of the income distribution at the age of 40 years had an expected age of death of 72.7 years. Men in the top 1% of the income distribution had an expected age of death of 87.3 years, which is 14.6 years (95% CI, 14.4-14.8 years) longer than those in the bottom 1%. Women in the bottom 1% of the income distribution at the age of 40 years had an expected age of death of 78.8 years. Women in the top 1% had an expected age of death of 88.9 years, which is 10.1 years (95% CI, 9.9-10.3 years) longer than those in the bottom 1%.

The gap in life expectancy between men and women was narrower at higher income levels. In the bottom 1% of the income distribution, women lived 6.0 years (95% CI, 5.9-6.2 years) longer than men; in the top 1% of the income distribution, women lived only 1.5 years (95% CI, 1.3-1.8 years) longer than men.

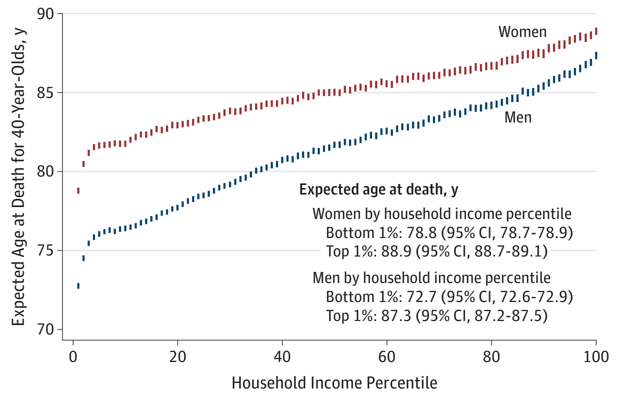
The relationship between life expectancy and income percentile was approximately linear above the 2 lowest income percentiles. However, the relationship between life expectancy and dollar income amount was concave (eFigure 8 in the Supplement). That is, an increase in income of a given dollar amount was associated with smaller gains in life expectancy at higher income levels. For example, increases in income from $14 000 to $20 000 (the 10th vs the 15th income percentiles), $161 000 to $224 000 (the 90th vs the 95th income percentiles), and $224 000 to $1.95 million (the 95th vs the 100th income percentiles) were all associated with approximately the same difference in life expectancy (ie, an increase of 0.7-0.9 years, averaging men and women).

Estimates of life expectancy grouping individuals based on individual earnings instead of household earnings were similar, as were estimates that used Gompertz extrapolations up to the age of 100 years instead of the age of 90 years (discussions of these and other sensitivity analyses appear in part IV of the eAppendix and in eFigure 9 in the Supplement).

National Trends in Life Expectancy by Income

The upper panels of **Figure 3** show race- and ethnicity-adjusted life expectancy for men and women by income quartile for each year from 2001 through 2014. There was a larger increase in life expectancy for higher income groups during the 2000s. For men, the mean annual increase in life expectancy from 2001 through 2014 was 0.20 years in the highest income quartile compared with only 0.08 years in the lowest income quartile ($P < .001$). For

Figure 2. Race- and Ethnicity-Adjusted Life Expectancy for 40-Year-Olds by Household Income Percentile, 2001-2014



Mean household income in thousands, $[a]					
Women	24	45	71	112	1.9 million
Men	26	50	77	119	2.0 million

Life expectancies were calculated using survival curves analogous to those in Figure 1. The vertical height of each bar depicts the 95% confidence interval. The difference between expected age at death in the top and bottom income percentiles is 10.1 years (95% CI, 9.9-10.3 years) for women and 14.6 years (95% CI, 14.4-14.8 years) for men. To control for differences in life expectancies across racial and ethnic groups, race and ethnicity adjustments were calculated using data from the National Longitudinal Mortality Survey and estimates were reweighted so that each income percentile bin has the same fraction of black, Hispanic, and Asian adults.

[a] Averaged across years and ages. The data are in thousands unless otherwise indicated.

women, the comparable changes were 0.23 years in the highest quartile and 0.10 years in the lowest quartile ($P < .001$). These differences persisted after controlling for the higher growth rate of income for individuals in the top quartile relative to the bottom quartile (eTable 4 in the Supplement).

The lower panels of Figure 3 show the annual increase in race-adjusted life expectancy by income ventiles. The annual increase in longevity was 0.18 years for men (which translates to an increase of 2.34 years from 2001-2014) and 0.22 years for women (an increase of 2.91 years from 2001-2014) in the top 5% of the income distribution. In the bottom 5% of the income distribution, the average annual increase in longevity was 0.02 years (an increase of 0.32 years from 2001-2014) for men and 0.003 years (an increase of 0.04 years from 2001-2014) for women ($P < .001$ for the differences between top and bottom 5% of income distributions for both sexes).

Local Area Variation in Life Expectancy by Income

Levels of Life Expectancy by Commuting Zone

Life expectancy varied significantly across areas within the United States, especially for low-income individuals. **Figure 4** shows life expectancy by income ventile for New York, New York; San Francisco, California; Dallas, Texas; and Detroit, Michigan. There was substantial variation across these areas for low-income individuals, but little variation for high-income individuals. Life expectancy ranged from 72.3 years to 78.6 years for men in the lowest income ventile across these 4 cities; the corresponding range for men in the top ventile was 86.5 years to 87.5 years.

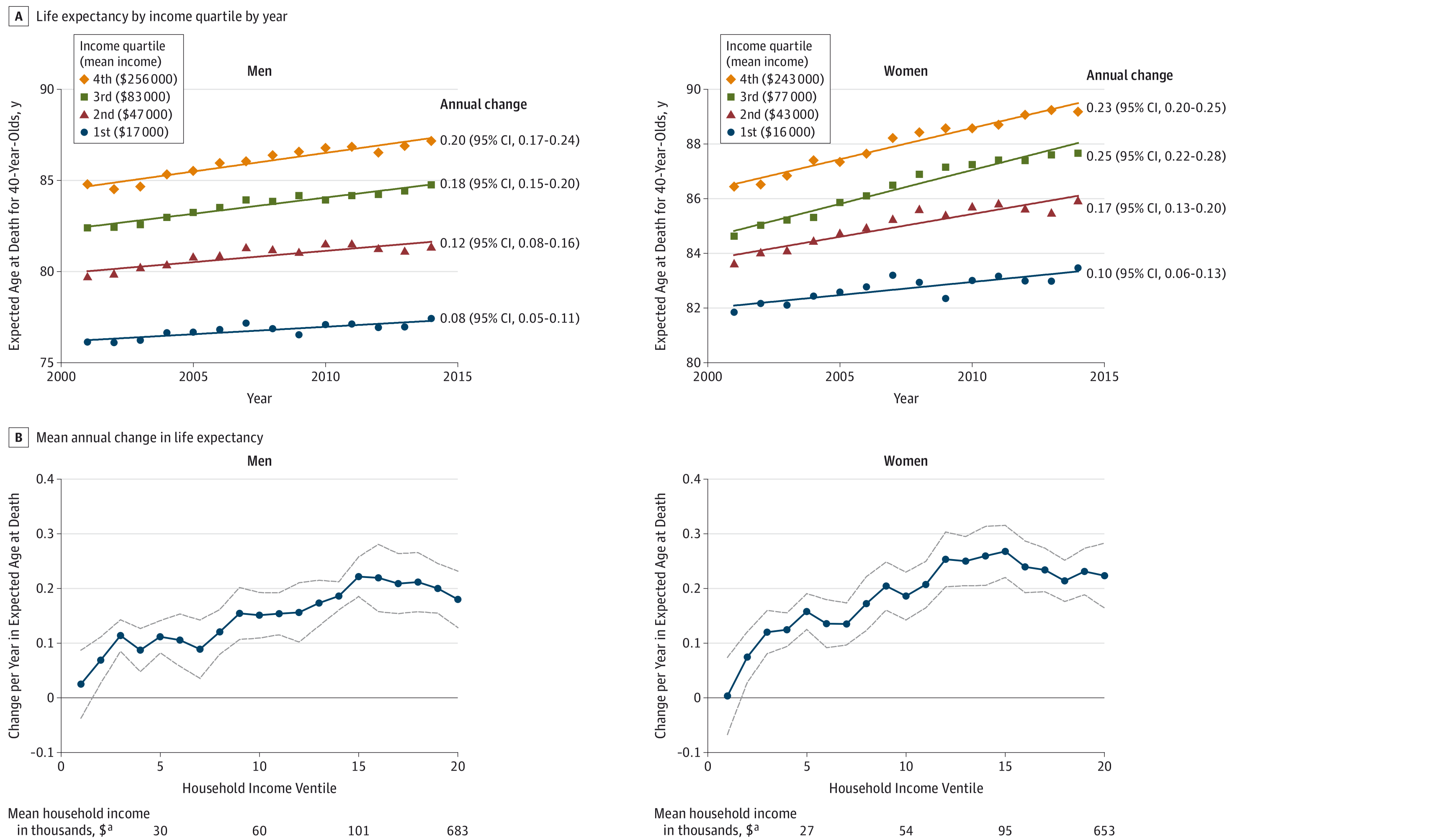
The results in Figure 4 are representative of the variation across commuting zones more generally. The SD of life expectancy across all commuting zones (weighted by population) was 1.39 years for men in the bottom income quartile vs 0.70 years in the top income quartile ($P < .001$). Life expectancy varied less across areas for women than men in the bottom income quartile, and the amount of variation across commuting zones also declined with income for women (eTable 5 in the Supplement).

Figure 5 shows maps of expected age at death by commuting zone for men and women in the bottom and top quartiles of the national income distribution (maps for the middle-income quartiles appear in eFigure 10 in the Supplement). For individuals in the bottom income quartile, life expectancy differed by about 5 years for men and 4 years for women between the lowest and highest longevity commuting zones ($P < .001$ for both sexes). A summary of standard errors by commuting zone appears in part V.C of the eAppendix and in eFigure 11.

Nevada, Indiana, and Oklahoma had the lowest life expectancies (<77.9 years) when men and women in the bottom income quartile were averaged. Of the 10 states with the lowest levels of life expectancy for individuals in the bottom income quartile, 8 formed a geographic belt from Michigan to Kansas (Michigan, Ohio, Indiana, Kentucky, Tennessee, Arkansas, Oklahoma, Kansas). The states with the highest life expectancies for individuals in the bottom income quartile (>80.6 years) were California, New York, and Vermont. Life expectancy in the South was similar to the national mean for both sexes (−0.22 years [$P = .47$] for women and −0.96 years [$P = .03$] for men) in the bottom income quartile. Individuals in the top income quartile had the lowest life expectancies (<85.3 years) in Nevada, Hawaii, and Oklahoma. Individuals in the top income quartile had the highest life expectancies (>87.6 years) in Utah; Washington, DC; and Vermont.

Table 1 lists the top 10 and bottom 10 commuting zones in mean life expectancy (averaging men and women) among the 100 most populated commuting zones for individuals in the bottom and top income quartiles. The expected age at death for the bottom quartile ranged from 74.2 years for men and 80.7 years for women in Gary, Indiana, to 79.5 years for men and 84.0 years for women in New York, New York. The commuting zones with the highest life expectancies

Figure 3. Changes in Race- and Ethnicity-Adjusted Life Expectancy by Income Group, 2001-2014

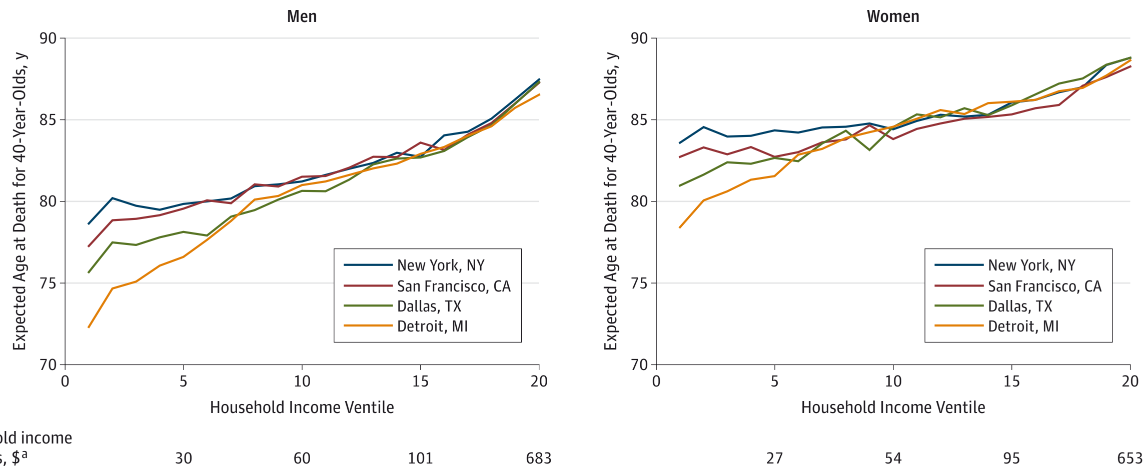


Scatter points in the A panels show the race- and ethnicity-adjusted life expectancy estimates by year and household income quartile. Solid lines represent best fit lines estimated using ordinary least-squares regression.

The B panels plot the slopes from analogous regressions estimated separately by income ventile (5 percentile point bins). Dashed lines show 95% confidence intervals.

[a] Averaged across years and ages.

Figure 4. Race- and Ethnicity-Adjusted Life Expectancy by Income Ventile in Selected Commuting Zones, 2001-2014



Estimates of race- and ethnicity-adjusted expected age at death for 40-year-olds computed by income ventile (5 percentile point bins).

[a] Averaged across years and ages.

were clustered in California (6 of the top 10), whereas the commuting zones with the lowest life expectancies were clustered in the industrial Midwest (5 of the bottom 10). The commuting zones with the highest life expectancies for those in the bottom income quartile also had the smallest gaps in life expectancy between the top and bottom quartiles ($r = -0.82$, $P < .001$). The expected age at death for the top income quartile ranged from 82.8 years for men and 85.3 years for women in Las Vegas, Nevada, to 86.6 years for men and 89.0 years for women in Salt Lake City, Utah. The areas with the highest and lowest life expectancies for those in the top income quartile were less clustered geographically; for example, California had commuting zones in both the top 10 and bottom 10 of the list.

The differences in life expectancy across commuting zones were similar in analyses with income measures adjusted for cost of living; with controls for differences across areas in the income distribution within each quartile; and using measures of loss in life years up to the age of 77 years that did not make use of extrapolations beyond observed ages (part IV.C of the eAppendix and eTable 6 in the Supplement). There was also considerable variation in life expectancy across counties within commuting zones (part V of the eAppendix, eFigure 12, and eTable 7).

Trends in Life Expectancy

Similar to levels of life expectancy, temporal trends varied significantly across geographic areas. **Figure 6** maps the annual change in life expectancy between 2001 and 2014 by state for men and women in the bottom income quartile. Hawaii, Maine, and Massachusetts had the largest gains in life expectancy (gaining >0.19 years annually) when men and women in the bottom income quartile were averaged. The states in which low-income individuals experienced the largest losses in life expectancy (losing >0.09 years annually) were Alaska, Iowa, and Wyoming.

Table 2 lists the top 10 and bottom 10 commuting zones in terms of trends in life expectancy (when averaging men and women) among the 100 most populated commuting zones for individuals in the bottom and top income quartiles. The estimated trends for individuals in the bottom income quartile ranged from an annual gain of 0.38 years in Toms River, New Jersey, to an annual loss of 0.17 years in Tampa, Florida. Gaps in life expectancy between the bottom and top income quartiles generally declined or remained stable in areas in which the bottom income quartile experienced the largest gains in life expectancy, such as Toms River, New Jersey. In contrast, gaps in life expectancy between the top and bottom income quartiles increased by approximately 0.3 years annually in places such as Tampa, Florida.

Figure 7 shows race- and ethnicity-adjusted life expectancies by year for men and women in the bottom income quartile in 2 commuting zones in the top 10 (Birmingham, Alabama, and Cincinnati, Ohio) and 2 commuting zones in the bottom 10 (Knoxville, Tennessee, and Tampa, Florida). This Figure shows that trends in life expectancy across these areas diverged continuously throughout the 2000s. For example, life expectancy increased by approximately 3.2 years from 2001 through 2014 for men and women in Cincinnati, Ohio, but declined by approximately 2.2 years in Tampa, Florida.

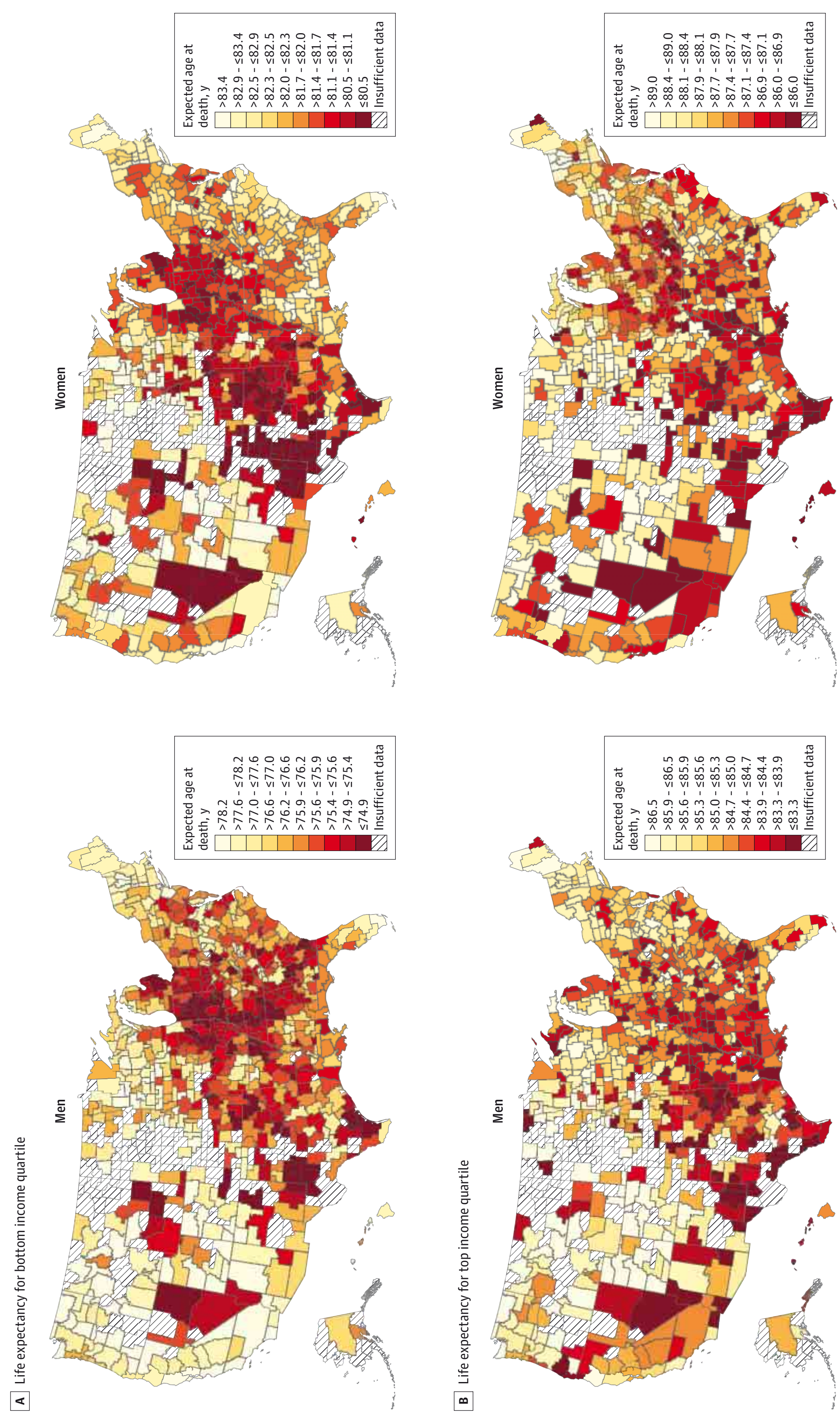
Correlates of Local Area Variation in Life Expectancy

Figure 8 shows correlations of commuting zone-level estimates of race- and ethnicity-adjusted life expectancy for the bottom income quartile with local area characteristics. The correlations are divided into 6 groups: health behaviors, access to health care, environmental factors, income inequality and social cohesion, local labor market conditions, and other factors. Data for men and women are combined; correlations were similar by sex (eTable 8 in the Supplement). County-level correlations were also similar (eTable 9).

Health Behaviors

Life expectancy was negatively correlated with rates of smoking ($r = -0.69$, $P < .001$) and obesity ($r = -0.47$, $P < .001$) and positively correlated with exercise rates ($r = 0.32$, $P = .004$) among individuals in the bottom income quartile. The maps for rates of smoking, obesity, and exercise among low-income individuals were similar to those for life expectancy (eFigure 13 in the Supplement).

Figure 5. Race- and Ethnicity-Adjusted Life Expectancy by Commuting Zone and Income Quartile, 2001-2014



Estimates of race- and ethnicity-adjusted expected age at death for 40-year-olds computed by commuting zone. The 595 commuting zones with populations above 25 000 are grouped into deciles and colored from dark to light as expected age at death increases. The second and third quartiles appear in eFigure 10 in the Supplement.

Table 1. Race- and Ethnicity-Adjusted Life Expectancy by Commuting Zone and Income Quartile, 2001-2014

Commuting Zone[a]	Rank[b]	Race- and Ethnicity-Adjusted Expected Age at Death (95% CI), y			Difference Between Top and Bottom Income Quartiles, Mean (95% CI), y
		Mean[c]	Men	Women	
Bottom Income Quartile[d]					
New York, NY	1	81.8 (81.6-82.0)	79.5 (79.3-79.8)	84.0 (83.7-84.4)	4.8 (4.5-5.0)
Santa Barbara, CA	2	81.7 (81.3-82.1)	79.4 (78.9-79.9)	84.0 (83.4-84.6)	5.8 (5.3-6.4)
San Jose, CA	3	81.6 (81.2-82.0)	79.5 (79.0-79.9)	83.7 (83.1-84.3)	4.7 (4.3-5.0)
Miami, FL	4	81.2 (80.9-81.6)	78.3 (77.8-78.7)	84.2 (83.7-84.8)	4.2 (3.9-4.5)
Los Angeles, CA	5	81.1 (80.9-81.4)	79.0 (78.7-79.3)	83.2 (82.8-83.6)	4.7 (4.5-4.9)
San Diego, CA	6	81.1 (80.8-81.4)	78.8 (78.5-79.1)	83.4 (83.0-83.8)	5.3 (5.0-5.6)
San Francisco, CA	7	80.9 (80.6-81.3)	78.8 (78.4-79.2)	83.0 (82.5-83.7)	5.2 (5.0-5.4)
Santa Rosa, CA	8	80.8 (80.5-81.2)	79.0 (78.6-79.5)	82.6 (82.1-83.1)	6.1 (5.6-6.6)
Newark, NJ	9	80.7 (80.5-80.9)	78.2 (78.0-78.4)	83.2 (83.0-83.6)	5.6 (5.3-5.8)
Port St Lucie, FL	10	80.7 (80.5-80.9)	78.0 (77.8-78.3)	83.3 (83.1-83.7)	6.2 (5.9-6.5)
Entire United States		79.4 (79.4-79.5)	76.7 (76.7-76.8)	82.1 (82.1-82.2)	7.0 (6.9-7.1)
San Antonio, TX	91	78.0 (77.6-78.4)	75.2 (74.7-75.7)	80.8 (80.1-81.5)	7.9 (7.4-8.4)
Louisville, KY	92	77.9 (77.7-78.2)	74.9 (74.6-75.3)	80.9 (80.5-81.3)	8.4 (8.0-8.8)
Toledo, OH	93	77.9 (77.6-78.2)	74.9 (74.6-75.4)	80.8 (80.3-81.3)	8.0 (7.5-8.4)
Cincinnati, OH	94	77.9 (77.7-78.1)	75.2 (74.9-75.5)	80.5 (80.2-80.9)	8.4 (8.0-8.8)
Detroit, MI	95	77.7 (77.5-77.8)	74.8 (74.6-75.0)	80.5 (80.3-80.8)	8.2 (8.0-8.4)
Tulsa, OK	96	77.6 (77.4-77.9)	74.9 (74.6-75.3)	80.3 (79.9-80.7)	8.2 (7.7-8.6)
Indianapolis, IN	97	77.6 (77.4-77.8)	74.6 (74.3-75.0)	80.6 (80.2-80.9)	8.5 (8.1-8.8)
Oklahoma City, OK	98	77.6 (77.3-77.8)	75.0 (74.7-75.3)	80.2 (79.8-80.5)	8.3 (7.9-8.7)
Las Vegas, NV	99	77.6 (77.4-77.8)	75.1 (74.9-75.3)	80.0 (79.7-80.3)	6.5 (6.2-6.8)
Gary, IN	100	77.4 (77.1-77.8)	74.2 (73.8-74.6)	80.7 (80.2-81.2)	7.2 (6.7-7.8)
Top Income Quartile[d]					
Salt Lake City, UT	1	87.8 (87.5-88.1)	86.6 (86.2-87.0)	89.0 (88.6-89.4)	8.3 (7.9-8.7)
Portland, ME	2	87.8 (87.3-88.2)	86.8 (86.3-87.5)	88.7 (88.0-89.4)	7.4 (6.8-7.9)
Spokane, WA	3	87.7 (87.2-88.1)	86.1 (85.4-86.8)	89.2 (88.7-89.9)	7.7 (7.2-8.3)
Santa Barbara, CA	4	87.5 (87.2-87.9)	86.3 (85.8-86.8)	88.7 (88.2-89.3)	5.8 (5.3-6.4)
Denver, CO	5	87.5 (87.3-87.7)	86.6 (86.3-86.9)	88.4 (88.1-88.7)	7.9 (7.6-8.2)
Minneapolis, MN	6	87.3 (87.1-87.5)	86.4 (86.1-86.7)	88.2 (88.0-88.5)	7.7 (7.4-8.0)
Grand Rapids, MI	7	87.3 (87.0-87.6)	86.2 (85.7-86.7)	88.4 (87.9-88.9)	8.1 (7.7-8.5)
Madison, WI	8	87.2 (86.8-87.7)	86.1 (85.5-86.7)	88.4 (87.9-89.0)	8.1 (7.5-8.7)
Eugene, OR	9	87.2 (86.9-87.6)	86.3 (85.8-86.9)	88.2 (87.7-88.8)	7.3 (6.8-7.8)
Springfield, MA	10	87.2 (86.8-87.7)	86.3 (85.8-86.9)	88.1 (87.5-88.8)	7.2 (6.6-7.9)
Entire United States		86.4 (86.3-86.5)	85.3 (85.2-85.4)	87.5 (87.4-87.6)	7.0 (6.9-7.1)
Youngstown, OH	91	85.8 (85.3-86.3)	84.6 (84.0-85.3)	86.9 (86.2-87.7)	6.7 (6.2-7.3)
Los Angeles, CA	92	85.8 (85.5-86.0)	84.9 (84.7-85.2)	86.6 (86.2-87.0)	4.7 (4.5-4.9)
Lakeland, FL	93	85.8 (85.2-86.3)	84.2 (83.4-85.0)	87.3 (86.6-88.2)	6.7 (6.1-7.3)
Miami, FL	94	85.4 (85.1-85.7)	84.3 (83.8-84.7)	86.6 (86.1-87.1)	4.2 (3.9-4.5)
Bakersfield, CA	95	85.0 (84.5-85.5)	84.1 (83.4-84.8)	86.0 (85.2-86.8)	6.1 (5.5-6.8)
El Paso, TX	96	85.0 (84.4-85.7)	83.2 (82.3-84.2)	86.7 (85.9-87.7)	5.9 (5.1-6.7)
Brownsville, TX	97	84.8 (84.1-85.7)	83.4 (82.4-84.5)	86.3 (85.3-87.6)	4.8 (3.9-5.7)
Honolulu, HI	98	84.8 (83.8-86.0)	84.2 (83.0-85.5)	85.3 (83.8-87.3)	6.6 (6.1-7.2)
Gary, IN	99	84.6 (84.2-85.1)	83.1 (82.5-83.7)	86.1 (85.5-86.8)	7.2 (6.7-7.8)
Las Vegas, NV	100	84.1 (83.8-84.4)	82.8 (82.4-83.2)	85.3 (84.9-85.8)	6.5 (6.2-6.8)

[a] Among the 100 most populous commuting zones. Only the top 10 and bottom 10 commuting zones appear in this Table.

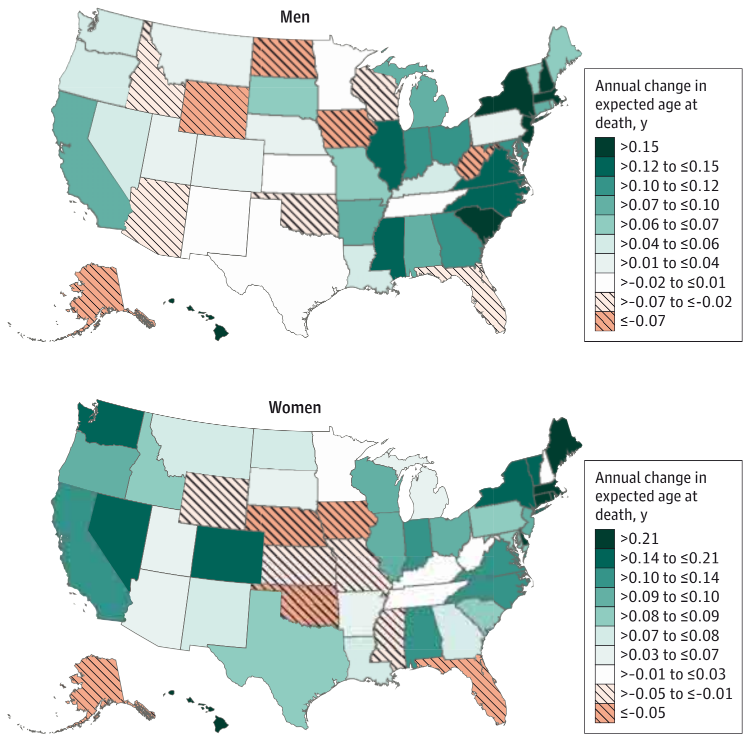
[b] A lower number (1-10) indicates a commuting zone with longer mean life expectancies, whereas a higher number (91-100) indicates a commuting zone with shorter mean life expectancies.

[c] Averaged across men and women.

[d] Based on the national distribution of household income.

Consistent with these findings, the NCHS data show that the majority of the variation in mortality rates across areas among individuals with low socioeconomic status was related to medical causes, such as heart disease and cancer, rather than external causes, such as vehicle crashes, suicide, and homicide (part V.E of the eAppendix and eTable 10).

Figure 6. Mean Annual Change in Life Expectancy by State for Bottom Income Quartile, 2001-2014



Annual changes estimated using ordinary least-squares regression of race- and ethnicity-adjusted expected age at death for 40-year-olds on calendar year by state. States are grouped into deciles and colored from red to turquoise as annual change in expected age at death increases.

Access to Health Care

Measures of health insurance coverage and spending (the fraction of uninsured and risk-adjusted Medicare spending per enrollee) were not significantly associated with life expectancy for individuals in the bottom income quartile. Life expectancy was negatively correlated with hospital mortality rates ($r = −0.31$, $P < .001$), but was not significantly associated with the quality of primary care ($r = 0.05$; 95% CI, −0.19 to 0.29).

Environmental Factors and Residential Segregation

Theories positing that differences in mortality are driven by the physical environment (eg, exposure to air pollution or a lack of access to healthy food) suggest that the gap in life expectancy between rich and poor individuals should be larger in more residentially segregated cities. Empirically, in areas where rich and poor individuals are more residentially segregated, differences in life expectancy between individuals in the top and bottom income quartile were smaller ($r = −0.23$, $P = .09$). Individuals in the bottom income quartile who lived in more segregated commuting zones had higher levels of life expectancy ($r = 0.26$, $P = .04$).

Income Inequality and Social Cohesion

Life expectancy for individuals in the bottom quartile of the income distribution was not significantly associated with the Gini index of income inequality ($r = 0.20$, $P = .11$). Income inequality was more negatively correlated with life expectancy in the upper income quartiles (for the top quartile, $r = −0.37$, $P < .001$; **Figure 9** and eFigure 14 in the Supplement). Life expectancy for individuals in the bottom quartile was negatively correlated with the social capital index ($r = −0.26$, $P = .05$) and not significantly associated with religiosity ($r = 0.12$, $P = .39$). There was no significant association between race- and ethnicity-adjusted life expectancy in the bottom income quartile and the fraction of black residents in the commuting zone ($r = −0.06$, $P = .62$).[27]

Local Labor Market Conditions

Unemployment rates, changes in population, and changes in the size of the labor force (all measures of local labor market conditions) were not significantly associated with life expectancy among individuals in the bottom income quartile.

Other Correlates

Associations between life expectancy for the bottom income quartile and 20 other factors were assessed (eTable 8 in the Supplement). The strongest correlates were the local area fraction of immigrants ($r = 0.72$, $P < .001$), median home values ($r = 0.66$, $P < .001$), local government expenditures per capita ($r = 0.57$, $P < .001$), population density ($r = 0.48$, $P < .001$), and the fraction of college graduates ($r = 0.42$, $P < .001$) (Figure 8). Population density and the fraction of college graduates were also significantly positively associated with trends in life expectancy across commuting zones for individuals in the bottom income quartile (eFigure 15).

Similar to individuals in the bottom income quartile, small area variation in life expectancy for individuals in the top income quartile was correlated with health behaviors (eg, for exercise

Table 2. Annual Change in Race- and Ethnicity-Adjusted Life Expectancy by Commuting Zone and Income Quartile, 2001-2014

Commuting Zone[a]	Rank[b]	Annual Change in Race- and Ethnicity-Adjusted Expected Age at Death (95% CI), y			Difference Between Top and Bottom Income Quartiles, Mean (95% CI), y
		Mean[c]	Men	Women	
Bottom Income Quartile[d]					
Toms River, NJ	1	0.38 (0.24 to 0.52)	0.45 (0.29 to 0.63)	0.30 (0.08 to 0.52)	−0.15 (−0.34 to 0.05)
Birmingham, AL	2	0.29 (0.18 to 0.41)	0.20 (0.07 to 0.35)	0.37 (0.20 to 0.55)	−0.43 (−0.66 to −0.20)
Richmond, VA	3	0.26 (0.13 to 0.39)	0.26 (0.11 to 0.42)	0.26 (0.06 to 0.45)	0.09 (−0.11 to 0.32)
Syracuse, NY	4	0.25 (0.11 to 0.40)	0.28 (0.13 to 0.47)	0.21 (−0.01 to 0.45)	−0.12 (−0.38 to 0.14)
Cincinnati, OH	5	0.24 (0.15 to 0.34)	0.27 (0.16 to 0.39)	0.21 (0.07 to 0.37)	0.09 (−0.08 to 0.28)
Fayetteville, NC	6	0.24 (0.10 to 0.38)	0.09 (−0.08 to 0.25)	0.39 (0.19 to 0.61)	−0.51 (−0.84 to −0.20)
Springfield, MA	7	0.23 (0.06 to 0.41)	0.22 (−0.00 to 0.43)	0.25 (0.00 to 0.53)	−0.12 (−0.42 to 0.18)
Gary, IN	8	0.22 (0.08 to 0.38)	0.24 (0.07 to 0.41)	0.21 (−0.04 to 0.46)	0.17 (−0.09 to 0.49)
Scranton, PA	9	0.21 (0.08 to 0.34)	0.10 (−0.04 to 0.25)	0.32 (0.11 to 0.54)	−0.03 (−0.28 to 0.22)
Honolulu, HI	10	0.21 (0.05 to 0.38)	0.04 (−0.17 to 0.24)	0.38 (0.12 to 0.66)	−0.18 (−0.50 to 0.11)
Entire United States		0.09 (0.07 to 0.11)	0.08 (0.05 to 0.11)	0.10 (0.06 to 0.13)	0.13 (0.10 to 0.16)
Cape Coral, FL	91	−0.07 (−0.21 to 0.06)	0.05 (−0.13 to 0.21)	−0.19 (−0.41 to 0.02)	0.26 (0.01 to 0.54)
Miami, FL	92	−0.07 (−0.14 to −0.01)	−0.08 (−0.17 to −0.01)	−0.06 (−0.16 to 0.03)	0.39 (0.25 to 0.54)
Tucson, AZ	93	−0.07 (−0.20 to 0.05)	−0.08 (−0.24 to 0.08)	−0.07 (−0.26 to 0.13)	0.23 (−0.00 to 0.50)
Albuquerque, NM	94	−0.08 (−0.22 to 0.06)	−0.13 (−0.30 to 0.05)	−0.03 (−0.26 to 0.21)	0.20 (−0.08 to 0.47)
Sarasota, FL	95	−0.08 (−0.20 to 0.03)	−0.09 (−0.25 to 0.06)	−0.08 (−0.26 to 0.09)	0.27 (0.05 to 0.51)
Des Moines, IA	96	−0.10 (−0.30 to 0.08)	−0.02 (−0.25 to 0.20)	−0.19 (−0.53 to 0.08)	0.41 (0.11 to 0.75)
Bakersfield, CA	97	−0.12 (−0.28 to 0.03)	−0.22 (−0.42 to −0.02)	−0.02 (−0.27 to 0.21)	−0.01 (−0.33 to 0.29)
Knoxville, TN	98	−0.12 (−0.26 to 0.01)	−0.13 (−0.29 to 0.03)	−0.11 (−0.33 to 0.09)	0.23 (−0.01 to 0.48)
Pensacola, FL	99	−0.15 (−0.30 to −0.02)	−0.16 (−0.38 to 0.02)	−0.15 (−0.40 to 0.08)	0.41 (0.13 to 0.70)
Tampa, FL	100	−0.17 (−0.25 to −0.09)	−0.16 (−0.25 to −0.07)	−0.18 (−0.30 to −0.06)	0.28 (0.11 to 0.46)
Top Income Quartile[d]					
El Paso, TX	1	0.48 (0.18 to 0.84)	0.23 (−0.18 to 0.66)	0.73 (0.33 to 1.24)	0.50 (0.18 to 0.89)
Poughkeepsie, NY	2	0.44 (0.27 to 0.63)	0.35 (0.11 to 0.62)	0.52 (0.28 to 0.80)	0.31 (0.08 to 0.58)
Gary, IN	3	0.40 (0.17 to 0.67)	0.40 (0.12 to 0.76)	0.39 (0.03 to 0.75)	0.17 (−0.09 to 0.49)
Portland, ME	4	0.39 (0.14 to 0.65)	0.32 (0.02 to 0.63)	0.45 (0.06 to 0.89)	0.19 (−0.11 to 0.52)
Youngstown, OH	5	0.38 (0.14 to 0.70)	0.09 (−0.25 to 0.45)	0.67 (0.33 to 1.14)	0.33 (0.05 to 0.67)
Buffalo, NY	6	0.38 (0.25 to 0.51)	0.41 (0.22 to 0.59)	0.35 (0.14 to 0.54)	0.27 (0.11 to 0.44)
Manchester, NH	7	0.36 (0.21 to 0.55)	0.32 (0.11 to 0.54)	0.41 (0.18 to 0.67)	0.22 (0.03 to 0.44)
Richmond, VA	8	0.35 (0.19 to 0.54)	0.45 (0.22 to 0.70)	0.24 (−0.02 to 0.54)	0.09 (−0.11 to 0.32)
Cincinnati, OH	9	0.34 (0.20 to 0.49)	0.32 (0.14 to 0.55)	0.35 (0.15 to 0.56)	0.09 (−0.08 to 0.28)
Chicago, IL	10	0.33 (0.26 to 0.41)	0.27 (0.17 to 0.36)	0.40 (0.30 to 0.50)	0.19 (0.10 to 0.28)
Entire United States		0.22 (0.19 to 0.24)	0.20 (0.17 to 0.24)	0.23 (0.20 to 0.25)	0.13 (0.10 to 0.16)
Baton Rouge, LA	91	0.05 (−0.16 to 0.24)	0.22 (−0.09 to 0.51)	−0.12 (−0.41 to 0.17)	0.09 (−0.16 to 0.32)
Santa Rosa, CA	92	0.03 (−0.22 to 0.27)	0.00 (−0.32 to 0.32)	0.06 (−0.29 to 0.43)	−0.05 (−0.36 to 0.26)
Honolulu, HI	93	0.02 (−0.22 to 0.27)	−0.03 (−0.32 to 0.29)	0.08 (−0.29 to 0.46)	−0.18 (−0.50 to 0.11)
Salt Lake City, UT	94	0.01 (−0.13 to 0.14)	−0.04 (−0.24 to 0.15)	0.07 (−0.13 to 0.24)	−0.14 (−0.33 to 0.04)
Erie, PA	95	−0.00 (−0.35 to 0.31)	0.26 (−0.18 to 0.78)	−0.27 (−0.85 to 0.09)	0.03 (−0.39 to 0.36)
Rockford, IL	96	−0.03 (−0.33 to 0.26)	0.06 (−0.25 to 0.43)	−0.13 (−0.56 to 0.33)	−0.06 (−0.37 to 0.29)
Bakersfield, CA	97	−0.13 (−0.42 to 0.12)	−0.18 (−0.57 to 0.18)	−0.08 (−0.50 to 0.30)	−0.01 (−0.33 to 0.29)
Birmingham, AL	98	−0.15 (−0.34 to 0.05)	−0.10 (−0.37 to 0.16)	−0.19 (−0.47 to 0.12)	−0.43 (−0.66 to −0.20)
Fayetteville, NC	99	−0.27 (−0.57 to −0.00)	−0.37 (−0.70 to 0.01)	−0.18 (−0.63 to 0.21)	−0.51 (−0.84 to −0.20)
Lakeland, FL	100	−0.28 (−0.61 to 0.00)	−0.33 (−0.79 to −0.01)	−0.23 (−0.68 to 0.22)	−0.29 (−0.64 to 0.00)

[a] Among the 100 most populous commuting zones. Only the top 10 and bottom 10 commuting zones appear in this Table.

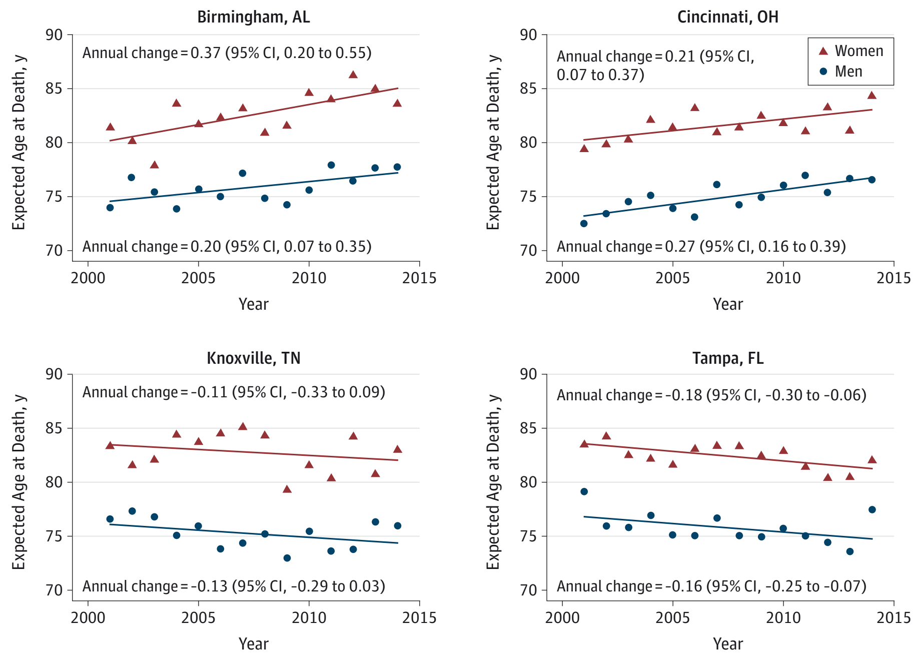
[b] A lower number (1-10) indicates a commuting zone with increasing mean life expectancies, whereas a higher number (91-100) indicates a commuting zone with decreasing or stable mean life expectancies.

[c] Averaged across men and women.

[d] Based on the national distribution of household income.

rates, *r* = 0.46, *P* < .001) (Figure 9). Correlations with measures of health care access were more mixed; for example, life expectancy was negatively correlated with Medicare expenditures per capita (*r* = −0.55, *P* < .001) but positively associated with the index of preventive care (*r* = 0.55, *P* < .001). There was no significant correlation with residential segregation. Income inequality was nega-

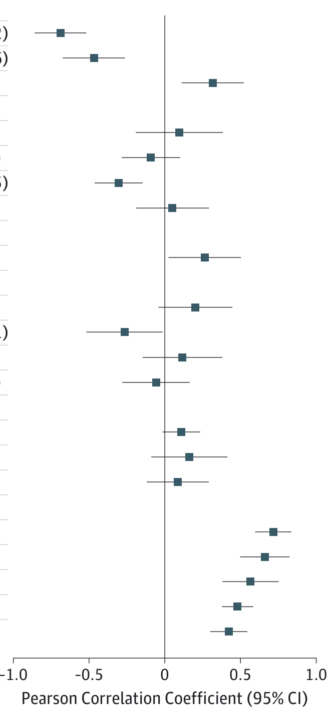
Figure 7. Expected Life Expectancy for Individuals in the Bottom Income Quartile Living in Selected Commuting Zones, 2001-2014



Solid lines indicate best linear fit, estimated using ordinary least-squares regression.

Figure 8. Correlations Between Life Expectancy in the Bottom Income Quartile and Local Area Characteristics, 2001-2014

	Pearson Correlation Coefficient (95% CI)
Health behaviors[a]	
Current smokers	-0.69 (-0.86 to -0.52)
Obesity	-0.47 (-0.67 to -0.26)
Exercise rate	0.32 (0.11 to 0.52)
Access to health care	
% Uninsured	0.10 (-0.19 to 0.38)
Medicare $ per enrollee	-0.09 (-0.28 to 0.10)
30-d Hospital mortality rate index	-0.31 (-0.46 to -0.15)
Index for preventive care	0.05 (0.19 to 0.29)
Environmental factors	
Income segregation	0.26 (0.02 to 0.51)
Income inequality and social cohesion	
Gini index	0.20 (-0.04 to 0.45)
Index for social capital	-0.26 (-0.52 to -0.01)
% Religious	0.12 (-0.15 to 0.38)
% Black adults	-0.06 (-0.28 to 0.17)
Local labor market conditions	
Unemployment rate in 2000	0.11 (-0.01 to 0.23)
% Change in population, 1980-2000	0.16 (-0.09 to 0.41)
% Change in labor force, 1980-2000	0.09 (-0.12 to 0.29)
Other factors	
% Immigrants	0.72 (0.60 to 0.84)
Median home value	0.66 (0.50 to 0.83)
Local government expenditures	0.57 (0.38 to 0.75)
Population density	0.48 (0.38 to 0.58)
% College graduates	0.42 (0.30 to 0.55)



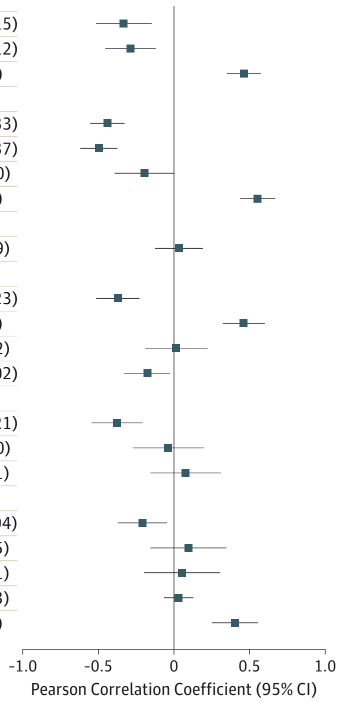
Population-weighted univariate Pearson correlations estimated between local area characteristics and race- and ethnicity-adjusted expected age at death for 40-year-olds in the bottom income quartile. These correlations were computed at the commuting zone level after averaging life expectancy across sexes. The error bars indicate 95% confidence intervals with errors clustered by state. Definitions and sources of all variables appear in eTable 3 in the Supplement.

[a] Among individuals in the bottom income quartile.

tively correlated with life expectancy for individuals in the top income quartile ($r = -0.37$, $P < .001$), as was the local unemployment rate ($r = -0.38$, $P < .001$). Among the factors most strongly correlated with life expectancy in the bottom income quartile, the fraction of immigrants was negatively correlated with life expectancy in the top income quartile ($r = -0.21$, $P = .02$), whereas the

Figure 9. Correlations Between Life Expectancy in the Top Income Quartile and Local Area Characteristics, 2001-2014

	Pearson Correlation Coefficient (95% CI)
Health behaviors[a]	
Current smokers	-0.33 (-0.51 to -0.15)
Obesity	-0.29 (-0.46 to -0.12)
Exercise rate	0.46 (0.35 to 0.58)
Access to health care	
% Uninsured	-0.44 (-0.55 to -0.33)
Medicare $ per enrollee	-0.50 (-0.62 to -0.37)
30-d Hospital mortality rate index	-0.19 (-0.39 to 0.00)
Index for preventive care	0.55 (0.44 to 0.67)
Environmental factors	
Income segregation	0.03 (-0.13 to 0.19)
Income inequality and social cohesion	
Gini index	-0.37 (-0.52 to -0.23)
Index for social capital	0.46 (0.32 to 0.60)
% Religious	0.02 (-0.19 to 0.22)
% Black adults	-0.18 (-0.33 to -0.02)
Local labor market conditions	
Unemployment rate in 2000	-0.38 (-0.54 to -0.21)
% Change in population, 1980-2000	-0.04 (-0.27 to 0.20)
% Change in labor force, 1980-2000	0.08 (-0.15 to 0.31)
Other factors	
% Immigrants	-0.21 (-0.37 to -0.04)
Median home value	0.10 (-0.16 to 0.35)
Local government expenditures	0.05 (-0.20 to 0.31)
Population density	0.03 (-0.06 to 0.13)
% College graduates	0.41 (0.25 to 0.56)



Population-weighted univariate Pearson correlations estimated between local area characteristics and race- and ethnicity-adjusted expected age at death for 40-year-olds in the top income quartile. These correlations were computed at the commuting zone level after averaging life expectancy across sexes. The error bars indicate 95% confidence intervals with errors clustered by state. Definitions and sources of all variables appear in eTable 3 in the Supplement.

[a] Among individuals in the top income quartile.

fraction of college graduates was positively correlated (r = 0.41, P < .001) with life expectancy.

Discussion

Addressing socioeconomic disparities in health is a major policy goal.[28-30] Yet the magnitude of socioeconomic gaps in life expectancy, how these gaps are changing over time, and their determinants remain debated. In this study, newly available data covering the US population were used to obtain more comprehensive and precise estimates of the relationship between income and life expectancy at the national level than was feasible in prior work. New local area estimates of life expectancy by income were calculated and factors that were correlated with higher life expectancy for individuals with low incomes were identified. The analysis yielded 4 major conclusions.

National Levels of Life Expectancy by Income

The first major conclusion is that life expectancy increased continuously with income. There was no dividing line above or below which higher income was not associated with higher life expectancy. Between the top 1% and bottom 1% of the income distribution, life expectancy differed by 15 years for men and 10 years for women (**Box**).

These differences are placed in perspective by comparing life expectancies at selected percentiles of the income distribution (among those with positive income) in the United States with mean life expectancies in other countries (eFigure 16 in the Supplement). For example, men in the bottom 1% of the income distribution at the age of 40 years in the United States have life expectancies similar to the mean life expectancy for 40-year-old men in Sudan and Pakistan, assuming that life expectancies in those countries are accurate. Men in the United States in the top 1% of the income distribution have higher life expectancies than the mean life expectancy for men in all countries at age 40 years.[31] The 10-year gap in life expectancy between women in the top 1% and bottom 1% of the US income distribution is equivalent to the decrement in longevity from lifetime smoking.[32]

National Trends in Life Expectancy by Income

The second major conclusion is that inequality in life expectancy increased in recent years. Between 2001 and 2014, individuals in the top 5% of the income distribution gained around 3 years of life expectancy, whereas individuals in the bottom 5% experienced no gains. As a benchmark for this magnitude, the NCHS estimates that eliminating all cancer deaths would increase life expectancy at birth by 3.2 years.[33]

This finding of increasing gaps in longevity supports the conclusions of recent studies using smaller samples.[6,7,10,11,14] However, the finding that life expectancy for women with the lowest incomes has not changed in recent years contrasts with the findings by Olshansky et al[11] that life expectancy has declined for women without a high school degree. The results in this study may differ because the group of people without a high school degree is an increasingly selected sample.[13]

Box. Key Messages

- Life expectancy increases continuously with income. At the age of 40 years, the gap in life expectancy between individuals in the top and bottom 1% of the income distribution in the United States is 15 years for men and 10 years for women.
- For individuals in the bottom income quartile, life expectancy at the age of 40 years differs by approximately 4.5 years between the commuting zones with the highest and lowest life expectancies. Adjusting for race and ethnicity, life expectancy for individuals with low incomes is lowest in Nevada, Indiana, and Oklahoma and highest in California, New York, and Vermont.
- Gaps in life expectancy by income increased between 2001 and 2014. Life expectancy did not change for individuals in the bottom 5% of the income distribution, whereas it increased by about 3 years for men and women in the top 5% of income distribution. These changes varied significantly across areas. The gap in life expectancy between the lowest and highest income quartiles decreased in some areas, such as areas within New Jersey and Alabama, but increased by more than 3 years in other areas, such as areas within Florida.
- Correlational analysis of the differences in life expectancy across geographic areas did not provide strong support for 4 leading explanations for socioeconomic differences in longevity: differences in access to medical care (as measured by health insurance coverage and proxies for the quality and quantity of primary care), environmental differences (as measured by residential segregation), adverse effects of inequality (as measured by Gini indices), and labor market conditions (as measured by unemployment rates). Rather, most of the variation in life expectancy across areas was related to differences in health behaviors, including smoking, obesity, and exercise. Individuals in the lowest income quartile have more healthful behaviors and live longer in areas with more immigrants, higher home prices, and more college graduates.

Case and Deaton[34] and Gelman and Auerbach[35] showed that age-adjusted mortality rates for white men aged 45 to 54 years were constant or increasing during the 2000s. Our finding of increasing life expectancy (decreasing mortality rates) across most income groups differs from this result because our estimates incorporate declines in mortality rates at older ages, pool all races, and exclude individuals with $0 income at the age of 40 years. However, our finding of increasing inequality in life expectancy across income groups is consistent with the finding by Case and Deaton[34] that among whites, mortality rates increased most rapidly for individuals with low levels of education.

Local Area Variation in Life Expectancy by Income

The third major conclusion is that life expectancy varied substantially across local areas. Among individuals in the bottom quartile of the income distribution, life expectancy differed by about 4 years for women and 5 years for men between commuting zones with the lowest and highest longevity. Trends in life expectancy during the 2000s varied substantially across areas as well, ranging from gains of more than 4 years between 2001 and 2014 in some commuting zones to losses of more than 2 years in others. These small area differences suggest that the increasing inequality in health outcomes in the United States as a whole is not immutable.

Prior work documenting geographic variation in longevity has been unable to disaggregate the variability across areas by income.[36-38] Disaggregating by income is important. When pooling all income groups, life expectancy in the South was well below average (eFigure 17 in the Supplement).[36-41] However, among individuals in the bottom income quartile, life expectancy in the South was more similar to the national mean. The shorter life expectancy in the South documented in prior work is explained partly by lower income levels rather than poorer health conditional on income. Among the population in the bottom income quartile, the shortest life expectancy was found in Oklahoma and in cities in the rust belt, such as Gary, Indiana, and Toledo, Ohio. There was also a substantial difference in life expectancy between low-income individuals in Nevada and Utah, as first documented by Fuchs.[42]

Correlates of Local Area Variation in Life Expectancy

Fourth, the variation in life expectancy across small areas was used as a lens to evaluate theories for socioeconomic differences in longevity. Understanding the characteristics of areas where low-income individuals live longer may yield insights into the determinants of longevity for low-income populations more broadly. The differences in life expectancy across areas were highly correlated with health behaviors (smoking, obesity, and exercise), suggesting that any theory for differences in life expectancy across areas must explain differences in health behaviors.

One such theory is that health and longevity are related to differences in medical care.[43-51] The present analysis provides limited support for this theory. Life expectancy for low-income individuals was not significantly correlated with measures of the quantity and quality of medical care provided, such as the fraction insured and measures of preventive care. The lack of a change in the mortality rates of low-income individuals when they become eligible for Medicare coverage at the age of 65 years (Figure 1) further supports the conclusion that a lack of access to care is not the primary reason that lower income individuals have shorter life expectancies.[50,51]

A second theory is that physical aspects of the local environment affect health, for example through exposure to air pollution.[52-59] Such theories predict that income gaps in longevity should be greater in areas with greater residential segregation by income. This explanation also does not find strong empirical support. Life expectancy among individuals in the lowest income quartile was higher in more segregated areas—both in absolute terms and relative to individuals in the highest income quartile.

A third theory is that poor health is related to inequality or a lack of social cohesion, which may increase stress for low-income individuals.[60,61] Consistent with prior work, in the current study the Gini index of income inequality was negatively correlated with average life expectancy across commuting zones when pooling all income groups ($r = -0.36$; $P = .002$).[38] However, this correlation is largely driven by areas with more inequality having a larger share of individuals in low-income quartiles, which is associated with lower mean life expectancy because the relationship between income and longevity is concave (eFigure 8 in the Supplement).[62-64] Among individuals in the bottom income quartile, there was no association between inequality and life expectancy across areas, consistent with the findings of Lochner et al[65] based on multilevel data.

Inequality was more negatively correlated with life expectancy for individuals in the highest income quartile, contrary to the prediction that inequality has the most adverse effects on the health of low-income individuals. At the state level, the correlations between inequality and life expectancy were negative when pooling all income groups, consistent with evidence reviewed by Wilkinson and Pickett,[66] but the correlation with life expectancy in the bottom income quartile was still positive. There was also no positive correlation between other measures of social cohesion (ie, social capital and participation in religious organizations) and life expectancy for individuals in the lowest income quartile.[25,67-71]

A fourth theory is that life expectancy is related to local labor market conditions.[72,73] Empirically, neither unemployment nor long-term population and labor force change was significantly associated with life expectancy for individuals in the lowest income quartile.

None of the 4 theories for shorter life expectancy among low-income individuals was consistently supported by the data. Rather, the strongest pattern in the data was that low-income individuals tend to live longest (and have more healthful behaviors) in cities with highly educated populations, high incomes, and high levels of government expenditures, such as New York, New York, and San Francisco, California. In these cities, life expectancy for individuals in the bottom 5% of the income distribution was approximately 80 years. In contrast, in cities such as Gary, Indiana, and Detroit, Michigan, the expected age at death for individuals in the bottom 5% of the income distribution was approximately 75 years. Low-income individuals living in cities with highly educated populations and high incomes also experienced the largest gains in life expectancy during the 2000s.

There are many potential explanations for why low-income individuals who live in affluent, highly educated cities live longer. Such areas may have public policies that improve health (eg, smoking bans) or greater funding for public services, consistent with the higher levels of local government expenditures in these areas. Low-income individuals who live in high-income areas may also be influenced by living in the vicinity of other individuals who behave in healthier ways. Alternatively, the low-income population in such cities might have different characteristics, consistent with the larger share of immigrants in these areas. Testing between these theories is a key area for future research.

Implications for Practice and Policy

The small area variation in the association between life expectancy and income suggests that reducing gaps in longevity may require local policy responses. For example, health professionals could make targeted efforts to improve health among low-income populations in cities, such as Las Vegas, Nevada; Tulsa, Oklahoma; and Oklahoma City, Oklahoma. The strong association between geographic variation in life expectancy and health behaviors suggests that policy interventions should focus on changing health behaviors among low-income individuals. Tax policies and other local public policies may play a role in inducing such changes. The publicly available data at www.healthinequality.org provide a way to monitor local progress.

The findings also have implications for social insurance programs. The differences in life expectancy by income imply that the Social Security program is less redistributive than implied by its progressive benefit structure. Men and women in the top 1% of the income distribution can expect to claim Social Security and Medicare for 11.8 and 8.3 more years than men and women in the bottom 1% of the income distribution. Some have proposed indexing the age of eligibility for Medicare and full Social Security benefits to increases in life expectancy.[74] The differences in the increases in life expectancy across income groups and areas suggest that such a policy would have to be conditioned on income and location to maintain current levels of redistribution.[12]

Limitations

This study has several limitations. First, the life expectancy estimates relied on extrapolations of mortality rates after the age of 76 years (and the age of 63 years for the year-specific estimates). Although the geographic variation remains similar without extrapolating beyond the age of 76 years and the national NCHS data support these extrapolations, further work is needed to ensure their accuracy across income subgroups and geographic areas. The life expectancy estimates by year do not incorporate factors that may have affected mortality rates only after the age of 63 years, such as Medicare Part D in 2006.

Second, the relationships between income and life expectancy should not be interpreted as causal effects of having more money because income is correlated with other attributes that directly affect health.[75] Because of such unmeasured confounding factors, the causal effects of income on life expectancy are likely to be smaller than the associations documented in this study. In addition, the local area variation need not reflect the causal effects of living in a particular area and may be driven by differences in the characteristics of the residents of each area. Although the correlational analysis in this study cannot establish causal mechanisms, it is a step toward determining which theories for disparities in longevity deserve further consideration.

Third, some of the measures used (eg, the percentage of religiosity to represent social cohesion) are constructs based on limited empirical data. However, we are unaware of better measures that could have been used as proxies for the various constructs of interest.

Conclusions

In the United States between 2001 and 2014, higher income was associated with greater longevity, and differences in life expectancy across income groups increased over time. However, the association between life expectancy and income varied substantially across areas; differences in longevity across income groups decreased in some areas and increased in others. The differences in life expectancy were correlated with health behaviors and local area characteristics.

ARTICLE INFORMATION

Published Online: April 10, 2016. doi:10.1001/jama.2016.4226.

Author Contributions: Dr Chetty had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Chetty, Stepner, Cutler.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: All authors.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: All authors.
Obtained funding: Chetty, Cutler.
Administrative, technical, or material support: All authors.
Study supervision: Chetty, Cutler.

Conflict of Interest Disclosures: The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Cutler reported being on the academic and

policy advisory board for Kyruss Inc and receiving a small amount of stock for doing so (Kyruss Inc provides software solutions to help provider organizations match patients to health care providers, improve the quality of referral and appointment scheduling processes, and optimize health care provider capacity); having nonpaid positions at the Institute of Medicine, Alliance for Aging Research, National Bureau of Economic Research, Aging, Health Care, Public Economics, and Productivity programs, Employee Benefit Research Institute, National Academy of Social Insurance, Institute for Research on Poverty, Center for American Progress, and Center for Healthcare Transparency; receiving grants from the National Institutes of Health; and receiving personal fees from Novartis Princeton, MedForce, Veterans Health Administration, International Monetary Fund, National Council and Community Behavioral Healthcare, Delaware Health Sciences Alliance, Dartmouth College, Healthcare Financial Management Association, New York City Health and Hospitals Corporation, Robert W. Baird & Co, Healthcare Billing and Management Association, Cadence Health, Pompeu Fabra University, Aon Hewitt, American Health Lawyers Association, Parenteral Drug Association, UBS, Aetna, Toshiba, Ernst and Young, Yale University, Bank of America, and New York University. No other disclosures were reported.

Funding/Support: This research was supported by the US Social Security Administration (SSA) through grant RRC08098400-07 to the National Bureau of Economic Research as part of the SSA Retirement Research Consortium, and through funding from the National Institutes of Health (grant P01AG005842), the Social Sciences and Humanities Research Council of Canada, the Smith Richardson Foundation, and the Laura and John Arnold Foundation.

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: The opinions expressed in this article are those of the authors and do not necessarily reflect the views of the US Internal Revenue Service, the US Treasury Department, the Social Security Administration, the National Bureau of Economic Research, the National Longitudinal Mortality Study, the US Bureau of the Census, the National Heart, Lung, and Blood Institute, the National Cancer Institute, the National Institute on Aging, the National Center for Health Statistics, or any other agency of the federal government.

Additional Contributions: We thank Frina Lin, BA, and Jeremy Majerovitz, BA, who provided outstanding research assistance and were compensated for their work. We also thank Amitabh Chandra, PhD (Kennedy School of Government, Harvard University, Cambridge, Massachusetts), Victor Fuchs, PhD (Stanford University, Stanford, California), and Jonathan Skinner, PhD (Department of Economics, Dartmouth College, Hanover New Hampshire), who provided helpful comments but were not compensated.

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