The Reversal of Fortunes: Trends in County Mortality and Cross-County Mortality Disparities in the United States

Majid Ezzati[1,2*], Ari B. Friedman[2], Sandeep C. Kulkarni[2,3], Christopher J. L. Murray[1,2,4]

1 Harvard School of Public Health, Boston, Massachusetts, United States of America, **2** Initiative for Global Health, Harvard University, Cambridge, Massachusetts, United States of America, **3** University of California, San Francisco, California, United States of America, **4** Institute for Health Metrics and Evaluation, University of Washington, Seattle, Washington, United States of America

ABSTRACT

Background

Counties are the smallest unit for which mortality data are routinely available, allowing consistent and comparable long-term analysis of trends in health disparities. Average life expectancy has steadily increased in the United States but there is limited information on long-term mortality trends in the US counties This study aimed to investigate trends in county mortality and cross-county mortality disparities, including the contributions of specific diseases to county level mortality trends.

Methods and Findings

We used mortality statistics (from the National Center for Health Statistics [NCHS]) and population (from the US Census) to estimate sex-specific life expectancy for US counties for every year between 1961 and 1999. Data for analyses in subsequent years were not provided to us by the NCHS. We calculated different metrics of cross-county mortality disparity, and also grouped counties on the basis of whether their mortality changed favorably or unfavorably relative to the national average. We estimated the probability of death from specific diseases for counties with above- or below-average mortality performance. We simulated the effect of cross-county migration on each county's life expectancy using a time-based simulation model. Between 1961 and 1999, the standard deviation (SD) of life expectancy across US counties was at its lowest in 1983, at 1.9 and 1.4 y for men and women, respectively. Cross-county life expectancy SD increased to 2.3 and 1.7 y in 1999. Between 1961 and 1983 no counties had a statistically significant increase in mortality; the major cause of mortality decline for both sexes was reduction in cardiovascular mortality. From 1983 to 1999, life expectancy declined significantly in 11 counties for men (by 1.3 y) and in 180 counties for women (by 1.3 y); another 48 (men) and 783 (women) counties had nonsignificant life expectancy decline. Life expectancy decline in both sexes was caused by increased mortality from lung cancer, chronic obstructive pulmonary disease (COPD), diabetes, and a range of other noncommunicable diseases, which were no longer compensated for by the decline in cardiovascular mortality. Higher HIV/AIDS and homicide deaths also contributed substantially to life expectancy decline for men, but not for women. Alternative specifications of the effects of migration showed that the rise in cross-county life expectancy SD was unlikely to be caused by migration.

Conclusions

There was a steady increase in mortality inequality across the US counties between 1983 and 1999, resulting from stagnation or increase in mortality among the worst-off segment of the population. Female mortality increased in a large number of counties, primarily because of chronic diseases related to smoking, overweight and obesity, and high blood pressure.

The Editors' Summary of this article follows the references.

Funding: This research was supported by a cooperative agreement, awarded by the Centers for Disease Control and Prevention and the Association of Schools of Public Health (grant U36/CCU300430–23). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The contents of this article are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention or the Association of Schools of Public Health.

Competing Interests: The authors have declared that no competing interests exist.

Academic Editor: Thomas Novotny, Center for Tobacco Control Research and Education, United States of America

Citation: Ezzati M, Friedman AB, Kulkarni SC, Murray CJL (2008) The reversal of fortunes: Trends in county mortality and cross-county mortality disparities in the United States. PLoS Med 5(4): e66. doi:10.1371/journal.pmed.0050066

Received: July 2, 2007
Accepted: January 28, 2008
Published: April 22, 2008

Abbreviations: COPD, chronic obstructive pulmonary disease; NCHS, National Center for Health Statistics; SD, standard deviation

* To whom correspondence should be addressed. E-mail: majid_ezzati@harvard.edu

Introduction

Average life expectancy in the United States has increased steadily in the past few decades, rising by more than 7 y for men and more than 6 y for women between 1960 and 2000. Parallel to this aggregate improvement, there are large disparities in health and mortality across population subgroups defined by race, income, geography, social class, education, and community deprivation indices [1–18]. Furthermore, there is evidence that health and mortality disparities have persisted or even increased over time in both relative and absolute terms [2,10,11,15,19,20], indicating that the observed aggregate health gains may not have been distributed evenly.

Counties are an important unit of analysis in understanding trends in mortality disparities in the United States. First, county-level analysis helps assess health disparities in relation to place of residence, and therefore complements analysis by race, income, and other socioeconomic factors. Second, counties are the smallest measurable unit for which mortality data are routinely available, and county-level data allow analyses for small subgroups of the US population. For example, analysis of the US mortality statistics for 1997–2001 (pooled over 5 y to increase the number of observations in small counties) demonstrates that the highest and lowest county life expectancies in the United States were 18.2 and 12.7 y apart for males and females, respectively, compared to 6.7- and 4.9-y gaps between whites and blacks as a whole. Further, county definition is relatively invariant over time, allowing consistent and comparable long-term analysis of trends in health disparities. This consistency is an important advantage because even analysis by race may be affected by changes in self-reported race in census figures over time [21,22]. Finally, county-level socioeconomic data are available from the census, and cause-specific mortality data are available from the vital statistics. These two data sources allow analysis of trends in all-cause mortality as well as mortality from specific diseases, in relation to both the location of county of residence and its environmental and socioeconomic characteristics (see also Singh [10,20]).

We used data on all-cause mortality to analyze trends in mortality and mortality disparities in US counties for a period of approximately four decades (1961–1999), one of the longest trend analyses of mortality disparities in the United States to our knowledge. We also grouped counties on the basis of whether their mortality changed favorably or unfavorably relative to the national average, and identified those counties with mortality stagnation and increase. Finally, we examined the epidemiological (disease-specific mortality) and selected socioeconomic characteristics of counties with below- or above-average mortality performance.

Methods

We arranged the 3,141 US counties into 2,068 units, each consisting of one or multiple individual counties. There were two reasons for forming merged county units: (1) to avoid unstable death rates, smaller counties were merged with adjacent counties to form units with a total population of at least 10,000 males and 10,000 females in 1990 [14]; and (2) to account for changes in county definitions and lines, such as formation of new counties and reversion to non-county status. This grouping of counties created a consistent set of 2,068 individual or merged county units that represent the same physical land areas from 1959 through the present. Because borough-specific death statistics were not available prior to 1982 in New York City, its five separate counties were merged into a single unit. For each county unit, we calculated annual sex-specific life expectancies. Table 1 provides summary information on the sociodemographic characteristics of counties. We also calculated probabilities of death from all causes as well as from specific diseases and disease clusters in the following age groups: 0–4, 5–14, 15–44, 45–64, 65–74, and 75–84 y.

We report the standard deviation (SD) of life expectancies of the 2,068 county units in the United States, as well as life expectancy for counties that make up the 2.5% of the US population with the highest and lowest county life expectancies in each year, by sex. We also report changes in mortality from specific diseases for six groups of counties, defined on the basis of how their life expectancy changed in relation to the national sex-specific change as follows: group 1, counties whose life expectancy increased at a level (statistically) significantly higher than the national sex-specific mean; group 2, counties whose life expectancy increased at a level significantly higher than zero but not significantly distinguishable from the national sex-specific mean; group 3, counties whose life expectancy increased at a level significantly higher than zero but significantly less than the national sex-specific mean; group 4, counties whose life expectancy change was statistically indistinguishable from zero and from the national sex-specific mean; group 5, counties whose life expectancy change was statistically indistinguishable from zero and was significantly less than the national sex-specific mean; and group 6, counties whose life expectancy had a statistically significant decline. All statistical significance was assessed at 90%.

Data Sources

Mortality statistics, including county of residence and cause of death certified and coded according to the International Classification of Diseases (ICD) system, were obtained from the National Center for Health Statistics (NCHS). Standard public-use mortality files do not include geographic identifiers for deaths in counties with fewer than 100,000 people. We obtained county identifiers for all deaths for years 1959 through 2001 through a special request to the NCHS. County identifiers for years after 2001 were not provided to us by the NCHS. County population by age for 1960 and all years between 1970 and 2001 are publicly available through the US Census Bureau; data prior to 1990 were accessed through the US Census Bureau and for 1990 and later through the NCHS [22]. We estimated intercensal county population for 1959 and 1961–1969 using the 1960 and 1970 censual estimates and an exponential growth model.

We used the following data sources for county-level sociodemographic characteristics, and for cross-county migration: (1) proportion of population by race and urban/rural place of residence, US Census via American FactFinder (http://factfinder.census.gov/) (for the 1990 and 2000 censuses) and via the Inter-University Consortium for Political and Social Research (ICPSR) (http://www.icpsr.umich.edu) (for the 1960, 1970, and 1980 censuses); (2) education, US Census via the National Historical Geographic Information System

Table 1. Summary Statistics for Socioeconomic and Demographic Characteristics of the 2,068 County Units Used in the Analysis in the Year 1999

Sociodemographic Variable	Mean	SD	Median	Interquartile Range	Minimum	Maximum
Population	134,930	381,880	45,790	70,990	18,780	9,437,290
Average income ($)	18,530	4,070	17,850	4,280	7,220	45,930
Percent completing high school	81.3	7.0	82.5	9.8	42.0	95.5
Within-county Gini coefficient[a]	38.3	3.8	38.0	5.0	28.7	56.5
Male life expectancy (y)[b]	73.4	2.3	73.6	3.2	62.0	80.2
Female life expectancy (y)[b]	79.2	1.7	79.2	2.4	71.8	84.5
5-y in-migration (%)	21.0	6.4	20.0	7.9	7.4	56.9

[a]Summarized across all counties in the United States for the year 2000 because figures were only available for individual counties and not for merged county units in our analysis (http://www.socanth.uncc.edu/smoller/).
[b]Pooled over 1997–2001.
doi:10.1371/journal.pmed.0050066.t001

(http://www.nhgis.org/) (1970 and 1980) and via American FactFinder (1990 and 2000). Linear interpolation was used to estimate values for intermediate years; (3) per capita income, US Census (years 1979, 1989, and 1999) and County Databooks based on the US Census (years 1969, 1972, 1975, 1981, 1983, and 1988), both via ICPSR. Per-capita income for other years was interpolated using an exponential growth model. All income estimates were adjusted for inflation with 2000 as the base year; and (4) cross-county migration, IRS External Data Product "County-to-County Migration Flows" (see http://www.irs.gov/pub/irs-soi/prodserv.pdf), which contains tabulations of the number of individuals moving from each county to every other county, and their mean and median income, by matching the Taxpayer Identification Number and comparing zip codes of filing addresses from one year to the next. Detailed data to quantify cross-county migration for all counties were available for 1993–1999.

Statistical Methods for the Analysis of Mortality Data

We estimated life expectancy and probabilities of death between specific ages, from all causes combined as well as from specific diseases, using standard life table techniques [23]. Life tables for each county-year were constructed using age-specific death and population data in 5-y age groups. Following standard life table techniques [23], those surviving to 85 y of age were assigned a life expectancy equal to the inverse of their observed mortality rate. For each year in each county unit, we calculated life expectancy and probabilities of death by pooling death and population data over 5 y (the year of analysis and two years on each side) to reduce sensitivity to small numbers (e.g., life expectancy in 1999 used death and population data from 1997 to 2001). Therefore, data from 1959 to 2001 yielded life expectancy estimates for 1961–1999, presented in Dataset S2 for all county-years. National-level life expectancy was not affected by small number of deaths and was calculated using data from individual years.

We estimated uncertainty in county life expectancy, and in change in life expectancy over time, using a binomial simulation. In brief, the uncertainty in the age-specific death rate in each county depends on the number of deaths (numerator) (n) and population (denominator) (N), and can be characterized with a binomial parameter with an expected value of $p = n/N$ and a variance of $p \times (1 - p)/N$. We simulated 1,000 draws from this distribution for every age-sex combination in 1961, 1983, and 1999, leading to 1,000 life expectancies for each county-year in these 3 y. The distribution of the 1,000 differences in the randomly drawn life expectancies for 1961–1983 and for 1983–1999 was then used to calculate confidence intervals and establish the statistical significance for life expectancy change. Owing to computational constraints, we used 100 draws for estimating the confidence intervals for absolute disparity between counties at the extremes of mortality advantage and disadvantage. The total number of simulated life tables was 40,946,400, calculated from 737,035,200 death rates.

Effects of Cross-County Migration on Life Expectancy Change

We simulated the effect of cross-county migration on each county's life expectancy using a time-based simulation model. This analysis was only done for 1993–1999, for which sufficiently detailed cross-county migration data were available. For each year after 1993, simulated life expectancy in each of the 2,068 county units was calculated as the weighted sum of its own life expectancy from the previous year and those of immigrants from all other counties, with weights being equal to the proportion of the new population from each county (i.e., population mixing based on a $2,068 \times 2,068$ migration matrix). This analysis was done for both sexes combined, because sex-specific migration data were not available. We repeated this analysis using three alternative assumptions: (1) emigrants had the same life expectancy as those who stay in the county of origin; (2) the life expectancy of all emigrants was 1 y higher than the life expectancy of those who stayed in the country of origin; and (3) the life expectancy of the emigrants to counties with higher life expectancy was 1 y higher than those who stayed in the country of origin or migrated to counties of lower life expectancy. The last two scenarios were based on some evidence that migrants may be healthier than those who do not move [24,25]. In both scenarios, the life expectancy of the remaining population was adjusted downwards so that overall life expectancy was correctly calculated.

All analyses were done using Stata version 9.2 and ESRI ArcGIS version 9.2.

Results

Between 1961 and 1999, average life expectancy in the United States increased from 66.9 to 74.1 y for men and from

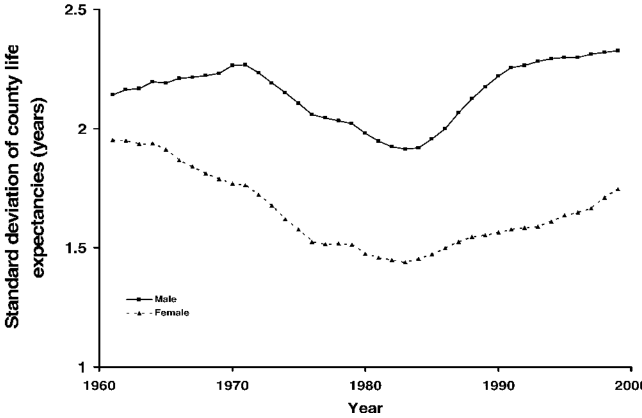

Figure 1. SD of Life Expectancies of the 2,068 County Units in the United States by Sex

Inequality in family income (e.g., as measured by the Gini coefficient) declined in the United States between the 1920s and 1970s, and has increased after that period [49,50].

doi:10.1371/journal.pmed.0050066.g001

73.5 to 79.6 y for women. The spread of male life expectancy across US counties, as measured by SD, rose slowly in the 1960s, then declined steeply until 1983 (1.9 y), when it began to rise again to 2.3 in 1999; the rate of increase declined in the 1990s (Figure 1). For women, cross-county life expectancy SD declined between 1961 and 1983 (from 2.0 y to 1.4 y), but rose steadily to 1.7 y in 1999. Cross-county life expectancy SD was always larger for men than for women.

In the early 1980s, the absolute disparity between counties at the extremes of mortality advantage and disadvantage also began to increase. For example, the difference between life expectancies of the counties that make up the 2.5% of the US population with the lowest and highest mortality in each year rose from 9.0 y in 1983 to 11.0 y in 1999 for men, and from 6.7 y to 7.5 y for women (Figure 2B). This widening gap was caused by stagnating improvements in life expectancy among the worst off, while the best off experienced consistent mortality decline (Figure 2A). Between 1961 and 1999, male life expectancy in counties with the lowest mortality rose from 70.5 to 78.7 y; the corresponding rise for females was from 76.9 to 83.0 y. Trends in the worst-off counties were more punctuated: Life expectancy increased in the 1960s and 1970s for females and in the 1970s for males. Starting in the early 1980s, life expectancy of the worst-off females remained relatively stable (68.7 y in 1961, 74.5 in 1983, and only 75.5 in 1999); that of the worst-off men had a period of decline, rising again in the 1990s. The stagnation of mortality among the worst off was primarily caused by a slowdown or halt of the earlier decline of cardiovascular mortality, coupled with a moderate rise in a number of other chronic diseases, for both sexes as well as HIV/AIDS and homicide for men.

Figure 3 groups counties by change in life expectancy, separately for 1961–1983 and 1983–1999, in relation to the sex-specific national average life expectancy change over the same period. Figure 4 shows the epidemiological characteristics of below- or above-average mortality reduction observed in Figure 3. Dataset S2 and Movies S1 and S2 show the estimated life expectancy for individual counties and for all years between 1961 and 1999. Figures S1 and S2 show the absolute change in county life expectancy for 1961–1983 and 1983–1999. Between 1961 and 1983, counties whose life expectancy increase was (statistically) significantly larger than the national average were primarily in the rural Deep South and the Eastern Seaboard, in the West from the Mexican border into the Rocky Mountains for both sexes, in Alaska, California, and Hawaii for men, and in the Dakotas and along the Mississippi River for women. During this same period, life expectancy improvements were significantly below the national average in the Midwest and Southern California for both sexes, in the Mississippi Delta for men, and in parts of the West Coast for women. In this period, the best-performing counties had the lowest average starting life expectancy of all groups in Figure 3 (66.1 y for men and 72.0 for women; Table 2), and the worst-performing ones had the highest starting life expectancy (68.9 for men and 77.6 y for women). This negative association between starting life expectancy and change in life expectancy supports the finding of shrinking cross-county mortality disparities. In 1961–1983, no counties had a statistically significant decline in sex-specific life expectancy at the 90% confidence level. The broad improvement of life expectancy observed during this period was primarily caused by major reductions in cardiovascular disease mortality for both sexes, compensating and surpassing the rise in cancers and chronic obstructive pulmonary disease (COPD). The distinction between those counties that performed better or worse than the national average in this period was primarily the rate of decline in cardiovascular diseases, with secondary effects from injuries and other noncommunicable diseases.

Between 1983 and 1999, male and female life expectancies had statistically significant decline in 11 and 180 counties, respectively (0.5% and 3.0% of the male and female populations); average decline in these counties was 1.3 y for both men and women. Another 48 and 783 counties had nonsignificant life expectancy decline for men and women (0.4% and 8.8% of the male and female populations), respectively. The average life expectancy decline in these counties was 0.5 y for women and 0.4 y for men, but these were not statistically significant because these counties were relatively small. Of the counties with statistically significant life expectancy decline, all for males and all but seven for females were in the Deep South, along the Mississippi River, and in Appalachia, extending into the southern portion of the Midwest and into Texas. There were also a number of counties with significant female life expectancy decline in the Rocky Mountain area and the Four Corners region, and one in Maine. Between 1983 and 1999, above-average mortality gain also became geographically more concentrated, and shifted to the Northeastern and Pacific Coast counties.

The decline in female life expectancy after 1983 was caused by a rise in mortality from lung cancer, COPD, diabetes, and a range of other noncommunicable diseases in the older ages (Figure 4; detailed numerical results available in Dataset S1). Female mortality from lung cancer, COPD, and even diabetes had also risen in 1961–1983, but this rise was surpassed by the decline in cardiovascular disease mortality. The rise in mortality for these causes in 1983–1999 was no longer compensated by the decline in cardiovascular mortality because cardiovascular decline became substantially smaller than it was in 1961–1983 (women in the worst-performing group, group 6, actually experienced a rise in cardiovascular mortality in the oldest age group). In 1983–1999, the rise in

Figure 2. Annual Absolute Life Expectancy Disparity between the Counties with the Highest and Lowest Life Expectancies

(A) Life expectancy for counties that make up the 2.5% of the US population with the highest and lowest county life expectancies in each year.
(B) Difference between highest and lowest life expectancies in (A). Data for each year show the combined life expectancy for counties that make up 2.5% of the US population and have the highest/lowest life expectancy for that year. The mean number of years that each county was in the highest/lowest life expectancy group was 7.9/10.5 y for men and 8.6/8.6 y for women.
The vertical lines show the 90% confidence interval (CI) for the estimated life expectancy or life expectancy difference. In each year, the 5% and 95% confidence limits correspond to the 5th and 95th percentiles of the distribution of life tables, calculated using the population-weighted average of death rates of constituent counties in 100 independent draws (see Methods).
doi:10.1371/journal.pmed.0050066.g002

HIV/AIDS and homicide deaths in young and middle-aged men was a major contributor to male, but not female, life expectancy decline. Mortality from diabetes, cancers, and COPD in the older ages also worsened in men but these continued to be countered by relatively large reductions in male cardiovascular mortality.

Between 1961 and 1983, counties with life expectancy improvement above and below the national average had relatively similar income levels; average county income was lower in those counties whose life expectancy change was below average and indistinguishable from zero (group 5), but these represented <1% of the female population (Table 2). Black women formed a larger proportion of the population in counties with above-average life expectancy improvement than in those counties with below-average life expectancy change; the pattern was reversed for men. After 1983, gain in life expectancy was positively associated with county income. The proportion of blacks was higher in counties with life expectancy decline, especially for men, but there were no detectable patterns of sociodemographic factors across other county groups in Figure 3.

If cross-county migration had been the only factor affecting any county's mortality, the SD of life expectancy in US counties would have declined from 1.89 y in 1993 to 1.71 in 1999 if emigrants had the same life expectancy as those who stayed in the county or origin; in practice it increased to 1.99 (Table 3). The SD in 1999 would have been 1.71 if emigrants had a life expectancy that was 1 y higher than those who stayed in the country of origin, and 1.78 if only those migrating to counties of higher life expectancy had a life expectancy 1 y higher than those who stayed in the country of origin or migrated to counties of lower life expectancy. In fact, only in extremely polarized migration scenarios—when migrants to counties with higher life expectancy have a 2.3-y advantage over those who stay in the county of origin—does the net effect of migration

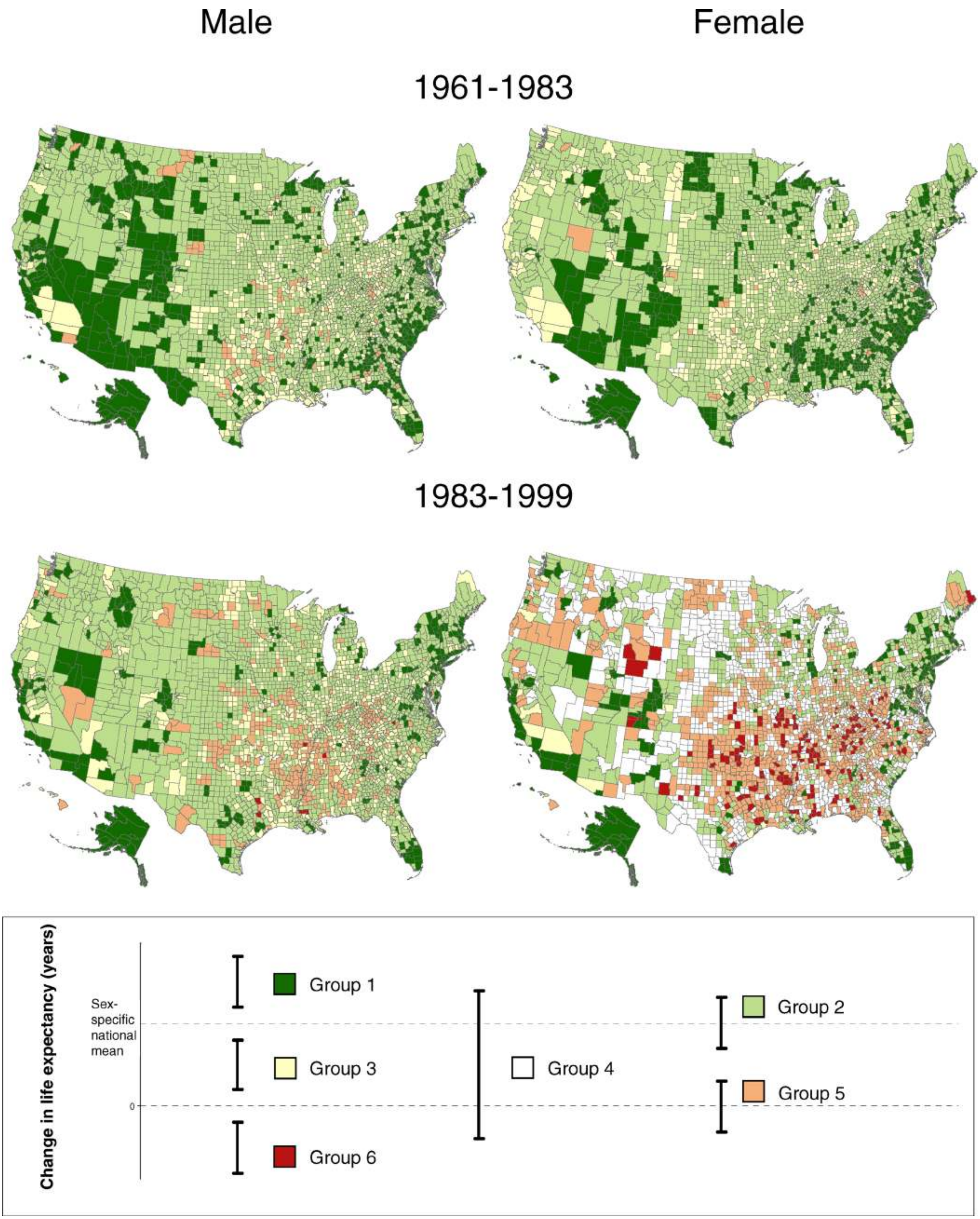

Figure 3. Change in County Life Expectancy in 1961–1983 and 1983–1999

Counties are categorized into six groups on the basis of how their life expectancy changed in relation to national sex-specific change in life expectancy (4.1 y for men and 4.8 y for women in 1961–1983; 3.1 y for men and 1.3 y for women in 1983–1999). Actual life expectancies are shown in Figure S1, and absolute changes in life expectancy are shown in Figure S2.

Group 1, life expectancy increased at a level significantly higher than the national sex-specific mean; group 2, life expectancy increased at a level

significantly higher than zero but not significantly distinguishable from the national sex-specific mean; group 3, life expectancy increased at a level significantly higher than zero but significantly less than the national sex-specific mean; group 4, life expectancy change was statistically indistinguishable from zero and from the national sex-specific mean; group 5, life expectancy change was statistically indistinguishable from zero and was significantly less than the national sex-specific mean; group 6, life expectancy had a statistically significant decline. All statistical significance was assessed at 90%.
doi:10.1371/journal.pmed.0050066.g003

become an increase, rather than a decrease, in cross-county life expectancy SD (for comparison, the change in national life expectancy in the United States was 2.3 y between 1982 and 1999). In 1993, individuals migrating to counties with lower life expectancy came from counties with an average life expectancy of 76.9 y; those migrating to counties with higher life expectancy came from counties with an average life expectancy of 75.2 y (with similar ordering for 1994–1999). Therefore, at the county level, migration seems to have worked to dampen the rising cross-country mortality inequality.

Discussion

Our analysis of county-level mortality demonstrates that the 1980s and 1990s marked an era of increased inequalities in mortality in the United States, measured both as the distribution of life expectancy in the US counties, and as the difference between the best-off and worst-off counties. Our finding on the decline and subsequent rise of mortality disparities across US counties would be the same using other metrics of mortality disparity, such as the interquartile range. Equally important is the finding that the higher disparity partly resulted from stagnation or increase in mortality among the worst-off segment of the population, with life expectancy for approximately 4% of the male population and 19% of the female population having had either statistically significant decline or stagnation. This stagnation and reversal of mortality decline, although affecting a minority of the nation's population, is particularly troubling because an oft-stated aim of the US health system is the improvement of the health of "all people, and especially those at greater risk of health disparities" (see for example http://www.cdc.gov/osi/goals/SIHPGPostcard.pdf).

Analyses of life expectancy of individual counties over these four decades showed worsening of life expectancy in a large number of counties after the early 1980s, especially among women. The majority of these counties were in the Deep South, along the Mississippi River, and in Appalachia, extending into the southern portion of the Midwest and into Texas. The rise in all-cause mortality was caused by an increase in cancers, diabetes, COPD, and a reduction in the rate of decline of cardiovascular diseases. There was also important influence of HIV/AIDS and homicide among men.

Harper et al. [18] found a widening gap in life expectancy between whites and blacks between 1983 and 1993, followed by a narrowing. To examine if the observed cross-county mortality distribution in Figure 1 is caused by a clustering of black population, we estimated the SD of county life expectancies separately for white and black populations of US counties in 1983–1999 (the race-specific analysis included all counties for whites and those counties with sufficient population and deaths to allow life expectancy calculation for blacks). Race-specific cross-county SD for white males and females and for black males mirrored the combined pattern seen in Figure 1; it remained relatively unchanged for black females. In other words, the observed trends in geographical mortality disparities were applicable even for the same race.

This study has a number of limitations. First, our analysis did not incorporate data after 2001 (leading to estimates up to 1999), because these data were not provided to us by the NCHS. However, the post-2001 data are particularly important for continued monitoring of mortality and mortality disparities in US counties, for example for the purpose of monitoring progress towards *Healthy People 2010* goals. Second, although counties provide the smallest unit of analysis for mortality and causes of death and are ideal for comparable analysis over time, they do not allow considering disparities within individual counties, especially in relation to sociodemographic factors. In the absence of detailed data on within-county mortality disparities, the cross-county SD does not directly measure total mortality inequalities in the United States (this applies to all analyses of population subgroups; see Gakidou et al. [26] for a discussion of within- and between-group health disparities). Third, analysis of cause-of-death data may be affected by regional variability in cause-of-death coding, which may also change over time [27]. The relatively broad disease categories (e.g., all cardiovascular diseases and clusters of cancers) used in our analysis have likely limited this effect. Fourth, the estimated uncertainty in life expectancy accounts for statistical uncertainty in death rates caused by (finite) population size and number of deaths. However, it was not possible to formally incorporate non-sampling error in death and population numbers. For example, population figures in the US censuses are not adjusted for under- and over-counts; the extent of under- and over-count may itself vary across counties or over time. Population and death figures have additional uncertainty owing to factors such as illegal or seasonal migrants and age misreporting. Finally, even the best-available data on migration could only provide indicative, versus conclusive, evidence of its role in trends in county mortality. The use of Internal Revenue Service migration data required making an assumption on the relative health status of emigrants, compared to nonmigrants. Alternative specifications of this assumption showed that migration still attenuated the rise in inequality, even when migrants were assumed to have substantial advantages in life expectancy. Therefore, although uncertainty about the precise relationship between the health of migrants and nonmigrants remains, it is unlikely that our findings on rising cross-county disparity are an artifact of migration. Although the mortality rates of cross-county migrants are not known, analysis of income data illustrates that, on average, family incomes of migrants were about $500 lower than nonmigrants in 1998–1999 (compared to a median 1999 national family income of $50,594). Detailed migration data were available only for 1993–1999; pre-1993 migration may have acted to further attenuate the true rise in mortality if it had the same pattern as the years in our analysis. It is, however, possible that the migration pattern differed in the earlier years of the analysis period. Although our results indicate that migration worked to attenuate the actual rise in

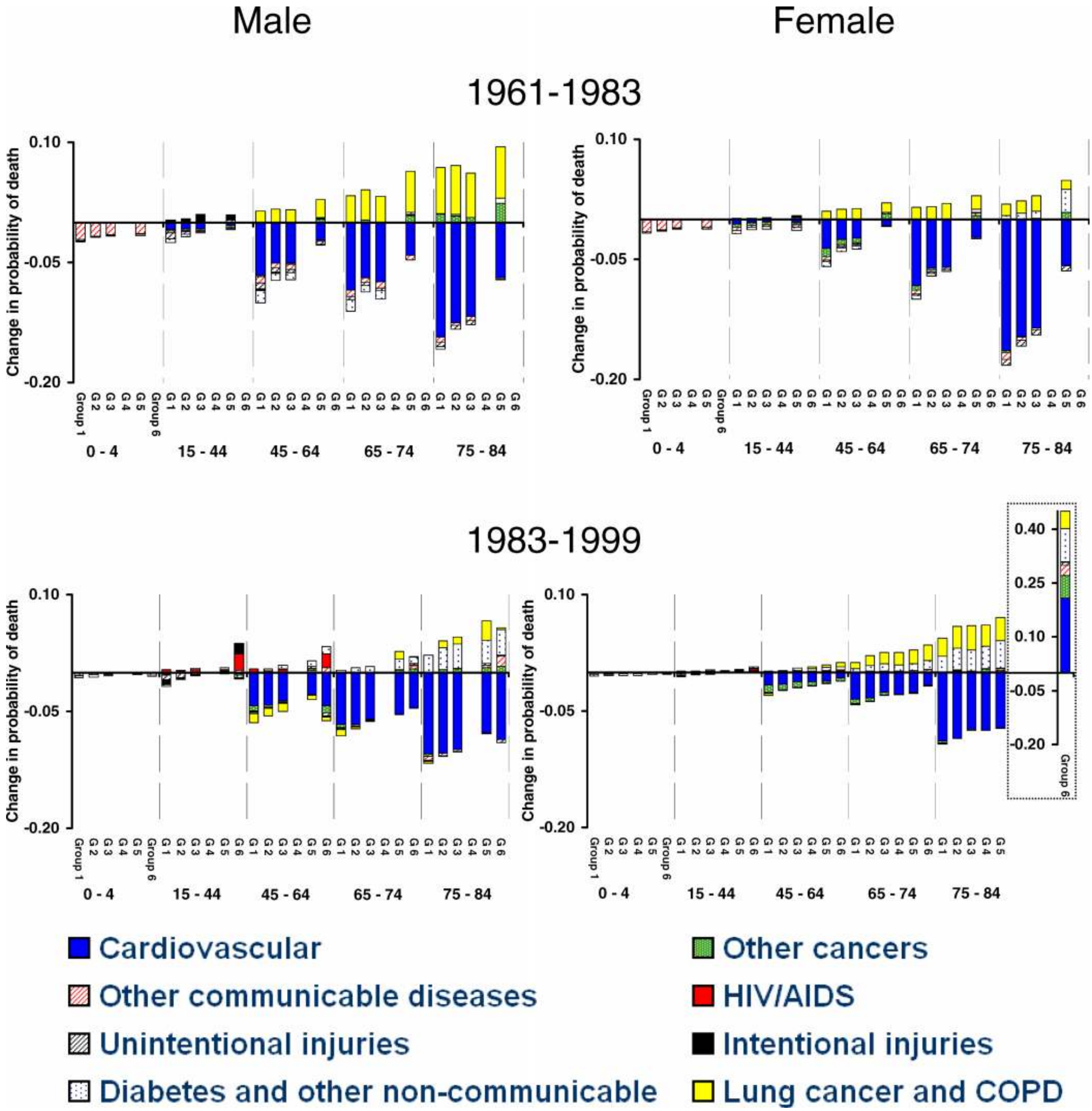

Figure 4. Change in Probability of Dying in Specific Age Ranges between 1961 and 1983 and between 1983 and 1999, with Counties Grouped on the Basis of the Level of Change in Life Expectancy as in Figure 3

The total height of each column shows the change in the probability of dying (from all causes) in the age range shown, divided into the probability of dying from specific diseases and injuries. The change is calculated as the probability of death in the end year minus that of the initial year. Therefore, a positive number indicates an increase in mortality, and a negative number indicates a decline in mortality (disease-specific or all-cause for the net effects of all diseases). Group 6 for females in 1983–1999 is shown on a different scale to increase resolution for all other groups.

Notes: Results are not shown for 5–14 y because there are few deaths in these ages in the United States. Groups with less than 0.2% of the country's population (groups 4 and 6 for both sexes in 1961–1983, and group 4 for males in 1983–1999) have not been shown because the results are based on too few deaths. COPD and lung cancer are presented together and changed in the same direction for all age and county group. The other noncommunicable disease group includes diabetes, for which the direction of change in probability of death is identical to other noncommunicable diseases exclusive of diabetes.

doi:10.1371/journal.pmed.0050066.g004

Table 2. Selected Socioeconomic and Demographic Characteristics of the Populations of the Counties Showing Significantly Above-Average, Average, and Below-Average (Including Stagnation or Decline) Life Expectancy Change

Gender	Sociodemographic Variable	Year													
		1961–1983							1983–1999						
Male	County group[a]	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	National	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	National
	Number of counties	609	1,983	454	2	102	0	3,150	299	1,871	542	4	423	11	3,150
	Beginning percent US population[b]	18.94	43.83	36.27	<0.2	0.95	0.00	100	30.91	41.29	23.51	< 0.2	3.82	0.45	100
	Ending percent US population[c]	23.24	42.91	32.91	<0.2	0.93	0.00	100	32.73	41.55	21.99	<0.2	3.36	0.35	100
	Beginning LE (y)[d]	66.1	67.1	66.6	N/A	68.9	N/A	66.9	71.3	71.1	70.4	N/A	70.4	67.0	71
	Ending LE (y)[e]	71.6	71.2	69.6	N/A	69.6	N/A	71	75.5	74.1	72.5	N/A	71.0	65.7	74.1
	Average income ($)[f]	11,907	11,405	12,770	N/A	8,717	N/A	12,122	16,964	13,502	13,946	N/A	10,695	11,600	14,563
	Income change (%)[g]	24	23	16	N/A	31	N/A	20	52	51	46	N/A	51	47	51
	Beginning average inequality index (Gini ×100)[h]	35.9	35.0	35.5	N/A	36.8	N/A	37.4	36.5	35.6	36.2	N/A	38.3	40.3	38.2
	Ending average inequality index (Gini ×100)[i]	36.0	35.3	37.2	N/A	37.5	N/A	38.2	41.4	38.5	39.9	N/A	40.0	44.6	42.9
	Percent completing high school[j]	81	84	84	N/A	88	N/A	83	65	72	73	N/A	79	77	70
	Percent black[k]	10.00	8.70	16.50	N/A	9.30	N/A	11.20	12.30	9.60	17.00	N/A	16.60	49.70	12.40
	Percent urban[l]	57	47	82	N/A	12	N/A	62	88	62	73	N/A	30	82	72
Female	County group[a]	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	National	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	National
	Number of counties	652	2,013	452	5	28	0	3,150	270	730	46	989	935	180	3,150
	Beginning percent US population[b]	24.96	41.82	32.93	<0.2	0.27	0.00	100	34.88	28.88	8.94	8.50	15.77	3.03	100
	Ending percent US population[c]	23.20	41.53	34.92	<0.2	0.33	0.00	100	35.39	29.74	8.94	8.10	15.12	2.71	100
	Beginning LE (y)[d]	72.0	73.7	74.1	N/A	77.6	N/A	73.5	78.1	78.3	78.1	78.6	78.5	77.9	78.3
	Ending LE (y)[e]	77.9	78.4	77.8	N/A	78.4	N/A	78.3	80.4	79.6	78.8	79.3	78.4	76.7	79.6
	Average income[f]	12,042	11,232	12,968	N/A	9,439	N/A	12,122	16,682	14,231	15,097	11,540	12,360	11,825	14,563
	Income change (%)[g]	19	23	19	N/A	37	N/A	20	52	50	45	51	48	45	51
	Beginning average inequality index (Gini ×100)[h]	36.8	35.4	34.4	N/A	36.4	N/A	37.4	36.9	35.1	35.8	36.6	36.3	37.5	38.2
	Ending average inequality index (Gini ×100)[i]	37.4	35.7	35.6	N/A	35.6	N/A	38.2	41.4	38.7	40.1	38	38.9	40.4	42.9
	Percent completing high school[j]	85	84	81	N/A	85	N/A	83	66	71	69	77	75	77	70
	Percent black[k]	16.70	9.90	11.20	N/A	12.90	N/A	11.20	13.90	11.40	16.40	9.60	12.00	18.70	12.40
	Percent urban[l]	68	45	79	N/A	23	N/A	62	90	71	90	31	48	49	72

The figures show averages across all counties in the group, weighted by county population. Information for groups with less than 0.2% of the US population is not shown because they are sensitive to small numbers. All figures for groups 1–6 are weighted by county population. For comparison, national figures are also shown. LE, life expectancy; N/A, not applicable.

[a]Group 1, life expectancy increased at a level significantly higher than the national sex-specific mean; group 2, life expectancy increased at a level significantly higher than zero but not significantly distinguishable from the national sex-specific mean; group 3, life expectancy increased at a level significantly higher than zero but significantly less than the national sex-specific mean; group 4, life expectancy change was statistically indistinguishable from zero and from the national sex-specific mean; group 5, life expectancy change was statistically indistinguishable from zero and was significantly less than the national sex-specific mean; group 6, life expectancy had a statistically significant decline. All statistical significance was assessed at 90%. See also Figure 3 for graphical presentation. Groups are defined on the basis of change over the period and therefore contain different counties in 1961–1983 than they do in 1983–1999.

[b]Percent of US population in the first year of the period (1961 and 1983).

[c]Percent of US population in the last year of the period (1983 and 1999).

[d]Life expectancy for the first year of the period (1961 and 1983).

[e]Life expectancy for the last year of the period (1983 and 1999).

[f]Income in the first year for which data were available in the period (1970 and 1983). Income data are for both sexes combined due to data availability.

[g]Percent change from the first year for which data were available in the period to the last year of the period (1970–1983 and 1983–1999).

[h]Average of within-county Gini coefficients in the first year in the analysis period for which data were available without interpolation (1970 and 1980). Source: http://www.unc.edu/~nielsen/data/data.htm for 1970–1990 and http://www.socanth.uncc.edu/smoller/ for 2000. The same methods were used in both sources and for all years. Because Gini coefficient is defined using a nonlinear relationship, national estimate would not be the same as the population-weighted average of individual counties.

[i]Average of within-county Gini coefficients for all counties in the group, in the last year in the analysis period for which data were available without interpolation (1980 and 2000). Because Gini coefficient is defined using a nonlinear relationship, national estimate would not be the same as the population-weighted average of individual counties.

[j]Percent having at least completed the 12th grade in the first year of the period for which data were available (1970 and 1983). The data have not been age standardized because of the format in which they are presented in the data sources. The implication is that cohort effects on education are not adjusted for in these estimates. The data are for both sexes combined due to data availability.

[k]Average of the first and last year of the period (i.e., 1961 and 1983, 1983 and 1999). The data are for both sexes combined due to data availability.

[l]Average of the first year for which data were available in the period (1970 and 1983) and the last year of the period (1983 and 1999). The data are for both sexes combined due to data availability.

doi:10.1371/journal.pmed.0050066.t002

Table 3. Cross-County SD of Life Expectancy in a Migration Simulation

Year	SD of Actual Life Expectancy	SD of Simulated Life Expectancy (Emigrant LE = Nonemigrant LE)	SD of Simulated Life Expectancy (Emigrant LE > Nonemigrant LE) for All Emigrants[a,b]	SD of Simulated Life Expectancy (Emigrant LE > Nonemigrant LE for Migrants to Counties with Higher LE)[c,d]
1993	1.89	1.89	1.89	1.89
1994	1.91	1.85	1.85	1.87
1995	1.92	1.82	1.82	1.85
1996	1.93	1.79	1.79	1.83
1997	1.95	1.76	1.76	1.81
1998	1.97	1.73	1.74	1.80
1999	1.99	1.71	1.71	1.78

For each year after 1993, life expectancy (LE) is calculated by "mixing" life expectancies from the previous year proportional to migration between any pair of counties (see Methods).
[a]The life expectancy of the emigrants was 1 y higher than the average life expectancy of the county of origin. The life expectancy of the corresponding nonmigrants was adjusted downwards proportionally so that overall life expectancy was correctly calculated.
[b]The estimated SDs are very similar to those in the scenario with emigrant LE = nonemigrant LE because migrants move to counties with higher as well as lower life expectancy.
[c]If the (emigrant LE = county of origin LE + 2.3) for migrants to counties with higher LE, then the cross-county SD in 1999 would be approximately 1.89; the advantage of migrants would have to be >3 y to lead to the observed SD of 1.99.
[d]The life expectancy of the emigrants to higher LE counties was 1 y higher than the average life expectancy of the county of origin. The life expectancy of the remaining population (nonmigrants and migrants to counties not of higher LE) was adjusted downwards proportionally so that overall life expectancy was correctly calculated.
doi:10.1371/journal.pmed.0050066.t003

mortality disparities, even an opposite effect (i.e., a situation in which the rise in disparities is a result of health-selective migration, especially in the worst-off counties) would be of public health and policy concern. A separate implication of cross-county migration is that, in counties with large population growth, a larger proportion of the population has recently immigrated from other counties. There was a weak relationship between change in life expectancy and population growth rate (correlation coefficients were 0.14 for 1961–1983 and 0.23 for 1983–1999).

Demographic and epidemiologic research has commonly documented the continued rise in life expectancy in the Western populations and the epidemiological dynamics and transitions that occur as mortality declines [28–30]. At the national level, the most notable examples of adult mortality rise are those in populations affected by the HIV/AIDS epidemic and in the former Soviet Union as a result of a rise in chronic diseases and injuries [31–35]. In high-income countries, there were periods of stagnation, or even slight increases, in adult mortality in the 1950s–1970s (e.g., in Australia, the Netherlands, and Norway), possibly as a result very high prevalence of smoking; the effects were substantially more pronounced among men [36,37]. To the best of our knowledge, Denmark is the only high-income country with a recent (1990s) increase in female mortality [38], possibly because of high smoking prevalence among Danish women [39]. Subnationally, recent analyses in Australia and the United Kingdom have found that an increase in mortality disparities was not accompanied by an actual rise in mortality in population subgroups; rather it was caused by differential rates of mortality decline [40,41].

HIV/AIDS mortality in the United States declined after the introduction of highly active antiretroviral therapy in the mid 1990s [42,43]. The remaining HIV/AIDS mortality in Figure 4 may be due to incomplete coverage and/or continued (albeit lower) mortality among the previously incident cases, itself due to treatment failure; the disparities in HIV/AIDS mortality could be caused by higher incidence or lower access and effectiveness in the worst-off groups. The rise in chronic disease mortality for relatively large segments of the American population, especially women, however, defies recent trends in other high-income countries. The epidemiological (disease-specific) patterns of female mortality rise are consistent with the geographical patterns of, and trends in, smoking, high blood pressure, and obesity [44–47]. In particular, the sex and cohort patterns of the increase in lung cancer and chronic respiratory disease mortality point to an important potential role for smoking (see also Preston and Wang [48]). The role of these risk factors in the reversal of the epidemiological transition should be further investigated, and programs that increase the coverage of interventions for chronic disease and injury risk factors in the worst-off counties, states, and regions should be established and regularly monitored and evaluated with respect to their local, versus aggregate only, impacts.

Supporting Information

Dataset S1. Change in Probability of Dying in Specific Age Ranges, with Counties Grouped on the Basis of Level of Change in Life Expectancy, Divided by Disease (Numerical Data for Figure 4)

Found at doi:10.1371/journal.pmed.0050066.sd001 (33 KB XLS).

Dataset S2. Life Expectancy at Birth by County, 1961–1999

Found at doi:10.1371/journal.pmed.0050066.sd002 (2.5 MB ZIP).

Figure S1. County Life Expectancy in (A) 1961; (B) 1983; and (C) 1999

Found at doi:10.1371/journal.pmed.0050066.sg001 (3.5 MB PPT).

Figure S2. Absolute Change in County Life Expectancy in (A) 1961–1983 and (B) 1983–1999

Found at doi:10.1371/journal.pmed.0050066.sg002 (2.4 MB PPT).

Movie S1. Life Expectancy at Birth by County, 1961–1999 (Males)

Found at doi:10.1371/journal.pmed.0050066.sv001 (14.4 MB AVI).

Movie S2. Life Expectancy at Birth by County, 1961–1999 (Females)

Found at doi:10.1371/journal.pmed.0050066.sv002 (15.8 MB AVI).

Acknowledgments

Author contributions. ME, ABF, SCK, and CJLM designed the study. SCK collected data for the study. ME, ABF, and SCK analyzed

the data. ME and ABF wrote the first draft of the paper. SCK and CJLM contributed to writing the paper.

References

1. Hahn RA, Eberhardt S (1995) Life expectancy in four U.S. racial/ethnic populations: 1990. Epidemiology 6: 350–355.
2. Cooper R, Cutler J, Desvigne-Nickens P, Fortmann SP, Friedman L, et al. (2000) Trends and disparities in coronary heart disease, stroke, and other cardiovascular diseases in the United States: findings of the national conference on cardiovascular disease prevention. Circulation 102: 3137–3147.
3. Geronimus AT, Bound J, Waidmann TA, Hillemeier MM, Burns PB (1996) Excess mortality among blacks and whites in the United States. N Engl J Med 335: 1552–1558.
4. Geronimus AT, Bound J, Waidmann TA (1999) Poverty, time, and place: variation in excess mortality across selected US populations, 1980–1990. J Epidemiol Community Health 53: 325–334.
5. Hahn RA, Eaker ED, Barker ND, Teutsch SM, Sosniak WA, et al. (1996) Poverty and death in the United States. Int J Health Serv 26: 673–690.
6. Navarro V (1990) Race or class versus race and class: mortality differentials in the United States. Lancet 336: 1238–1240.
7. Singh GK, Miller BA (2004) Health, life expectancy, and mortality patterns among immigrant populations in the United States. Can J Public Health 95: I14–I21.
8. Singh GK, Yu SM (1996) Trends and differentials in adolescent and young adult mortality in the United States, 1950 through 1993. Am J Public Health 86: 560–564.
9. Wong MD, Shapiro MF, Boscardin WJ, Ettner SL (2002) Contribution of major diseases to disparities in mortality. N Engl J Med 347: 1585–1592.
10. Singh GK (2003) Area deprivation and widening inequalities in US mortality, 1969–1998. Am J Public Health 93: 1137–1143.
11. Pappas G, Queen S, Hadden W, Fisher G (1993) The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986. N Engl J Med 329: 103–109.
12. Davey SG, Neaton JD, Wentworth D, Stamler R, Stamler J (1998) Mortality differences between black and white men in the USA: contribution of income and other risk factors among men screened for the MRFIT. MRFIT Research Group. Multiple Risk Factor Intervention Trial. Lancet 351: 934–939.
13. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV (2005) Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: The Public Health Disparities Geocoding Project. Am J Public Health 95: 312–323.
14. Murray CJ, Kulkarni SC, Michaud C, Tomijima N, Bulzacchelli MT, et al. (2006) Eight Americas: investigating mortality disparities across races, counties, and race-counties in the United States. PLoS Med 3: e260. doi:10.1371/journal.pmed.0030260
15. Feldman JJ, Makuc DM, Kleinman JC, Corioni-Huntley J (1989) National trends in educational differentials in mortality. Am J Epidemiol 129: 919–933.
16. Kaplan GA, Pamuk ER, Lynch JW, Cohen RD, Balfour JL (1996) Inequality in income and mortality in the United States: analysis of mortality and potential pathways. BMJ 312: 999–1003.
17. Steenland K, Henley J, Calle E, Thun M (2004) Individual- and area-level socioeconomic status variables as predictors of mortality in a cohort of 179,383 persons. Am J Epidemiol 159: 1047–1056.
18. Harper S, Lynch J, Burris S, Davey Smith G (2007) Trends in the black-white life expectancy gap in the United States, 1983–2003. JAMA 297: 1224–1232.
19. Williams JE, Massing M, Rosamond WD, Sorlie PD, Tyroler HA (1999) Racial disparities in CHD mortality from 1968–1992 in the state economic areas surrounding the ARIC study communities. Atherosclerosis Risk in Communities. Ann Epidemiol 9: 472–480.
20. Singh GK, Siahpush M (2006) Widening socioeconomic inequalities in US life expectancy, 1980–2000. Int J Epidemiol 35: 969–979.
21. Hahn RA, Truman BI, Barker ND (1996) Identifying ancestry: the reliability of ancestral identification in the United States by self, proxy, interviewer, and funeral director. Epidemiology 7: 75–80.
22. Ingram DD, Parker JD, Schenker N, Weed JA, Hamilton B, et al. (2003) United States Census 2000 population with bridged race categories. Vital Health Stat 2 135: 1–55.
23. Preston SH, Heuveline P, Guillot M (2001) Demography. Malden (Massachusetts): Blackwell.
24. Connolly S, O'Reilly D (2007) The contribution of migration to changes in the distribution of health over time: five-year follow-up study in Northern Ireland. Soc Sci Med 65: 1004–1011.
25. Fox AJ, Goldblatt PO, Adelstein AM (1982) Selection and mortality differentials. J Epidemiol Community Health 36: 69–79.
26. Murray CJ, Gakidou EE, Frenk J (1999) Health inequalities and social group differences: what should we measure? Bull World Health Organ 77: 537–543.
27. Murray CJL, Kulkarni SC, Ezzati M (2006) Understanding the coronary heart disease versus total cardiovascular mortality paradox: a method to enhance the comparability of cardiovascular death statistics in the United States. Circulation 113: 2071–2081.
28. Oeppen J, Vaupel J (2007) Broken limits to life expectancy. Science 296: 1029–1031.
29. Olshansky S, Ault A (1986) The fourth stage of the epidemiologic transition: the age of delayed degenerative diseases. Milbank Mem Fund Q 64: 355–391.
30. Riley JC (2001) Rising life expectancy: a global history. Cambridge (United Kingdom) and New York: Cambridge University Press.
31. National Academy Press (1997) Premature death in the new independent states. Washington, D.C.: National Academy Press.
32. McKee M, Shkolnikov V (2001) Understanding the toll of premature death among men in eastern Europe. BMJ 323: 1051–1055.
33. Shkolnikov V, Mesle F, Vallin J (1996) Health crisis in Russia. II. Changes in causes of death: a comparison with France and England and Wales (1970 to 1993). Population 8: 155–189.
34. Shkolnikov V, Mesle F, Vallin J (1996) Health crisis in Russia. I. Recent trends in life expectancy and causes of death from 1970 to 1993. Population 8: 123–154.
35. Shkolnikov V, McKee M, Leon D (2001) Changes in life expectancy in Russia in the mid-1990s. Lancet 357: 917–921.
36. Taylor R, Lewis M, Powles J (1998) The Australian mortality decline: all-cause mortality 1788–1990. Aust N Z J Public Health 22: 27–36.
37. Taylor R, Lewis M (1998) The Australian mortality decline: cause-specific mortality 1907–1990. Aust N Z J Public Health 22: 37–44.
38. Department of Economic and Social Affairs (2005) World population prospects the 2004 revision: population database. New York: United Nations Population Division.
39. World Health Organization (1997) Tobacco or health: a global status report. Geneva: World Health Organization.
40. Raleigh V, Kiri V (1997) Life expectancy in England: variations and trends by gender, health authority, and level of deprivation. J Epidemiol Community Health 51: 649–658.
41. Hayes L, Quine S, Taylor R (2005) New South Wales trends in mortality differentials between small rural and urban communities over a 25-year period, 1970–1994. Aust J Rural Health 13: 71–76.
42. Centers for Disease Control and Prevention (CDC) (2006) Epidemiology of HIV/AIDS — United States, 1981–2005. MMWR Morb Mortal Wkly Rep 55: 589–592.
43. Selik RM, Byers RH Jr., Dworkin MS (2002) Trends in diseases reported on US death certificates that mentioned HIV infection, 1987–1999. J Acquir Immune Defic Syndr 29: 378–387.
44. Ezzati M, Martin H, Skjold S, Vander Hoorn S, Murray CJL (2006) Trends in national and state-level obesity in the USA after correction for self-report bias: analysis of health surveys. J Roy Soc Med 99: 250–257.
45. Ezzati M, Oza S, Danaei G, Murray CJL (2008) Trends and cardiovascular mortality effects of state-level blood pressure and uncontrolled hypertension in the United States. Circulation 117: 905–914.
46. Hicks LS, Fairchild DG, Cook EF, Ayanian JZ (2003) Association of region of residence and immigrant status with hypertension, renal failure, cardiovascular disease, and stroke, among African-American participants in the third National Health and Nutrition Examination Survey (NHANES III). Ethn Dis 13: 316–323.
47. Obisesan TO, Vargas CM, Gillum RF (2000) Geographic variation in stroke risk in the United States. Region, urbanization, and hypertension in the Third National Health and Nutrition Examination Survey. Stroke 31: 19–25.
48. Preston SH, Wang H (2006) Sex mortality differences in the United States: the role of cohort smoking patterns. Demography 43: 631–646.
49. Nielsen F, Alderson AS (1997) The Kuznets Curve and the great u-turn: income inequality in US counties, 1970 to 1990. Am Sociol Rev 62: 12–33.
50. Harrison B, Bluestone B (1988) The great u-turn: corporate restructuring and the polarizing of America. New York: Basic Books.

Editors' Summary

Background. It has long been recognized that the number of years that distinct groups of people in the United States would be expected to live based on their current mortality patterns ("life expectancy") varies enormously. For example, white Americans tend to live longer than black Americans, the poor tend to have shorter life expectancies than the wealthy, and women tend to outlive men. Where one lives might also be a factor that determines his or her life expectancy, because of social conditions and health programs in different parts of the country.

Why Was the Study Done? While life expectancies have generally been rising across the United States over time, there is little information, especially over the long term, on the differences in life expectancies across different counties. The researchers therefore set out to examine whether there were different life expectancies across different US counties over the last four decades. The researchers chose to look at counties—the smallest geographic units for which data on death rates are collected in the US—because it allowed them to make comparisons between small subgroups of people that share the same administrative structure.

What Did the Researchers Do and Find? The researchers looked at differences in death rates between all counties in US states plus the District of Columbia over four decades, from 1961 to 1999. They obtained the data on number of deaths from the National Center for Health Statistics, and they obtained data on the number of people living in each county from the US Census. The NCHS did not provide death data after 2001. They broke the death rates down by sex and by disease to assess trends over time for women and men, and for different causes of death.

Over these four decades, the researchers found that the overall US life expectancy increased from 67 to 74 years of age for men and from 74 to 80 years for women. Between 1961 and 1983 the death rate fell in both men and women, largely due to reductions in deaths from cardiovascular disease (heart disease and stroke). During this same period, 1961–1983, the differences in death rates among/across different counties fell. However, beginning in the early 1980s the differences in death rates among/across different counties began to *increase*. The worst-off counties no longer experienced a fall in death rates, and in a substantial number of counties, mortality actually increased, especially for women, a shift that the researchers call "the reversal of fortunes." This stagnation in the worst-off counties was primarily caused by a slowdown or halt in the reduction of deaths from cardiovascular disease coupled with a moderate rise in a number of other diseases, such as lung cancer, chronic lung disease, and diabetes, in both men and women, and a rise in HIV/AIDS and homicide in men. The researchers' key finding, therefore, was that the differences in life expectancy across different counties initially narrowed and then widened.

What Do these Findings Mean? The findings suggest that beginning in the early 1980s and continuing through 1999 those who were already disadvantaged did not benefit from the gains in life expectancy experienced by the advantaged, and some became even worse off. The study emphasizes how important it is to monitor health inequalities between different groups, in order to ensure that everyone—and not just the well-off—can experience gains in life expectancy. Although the "reversal of fortune" that the researchers found applied to only a minority of the population, the authors argue that their study results are troubling because an oft-stated aim of the US health system is the improvement of the health of "all people, and especially those at greater risk of health disparities" (see, for example http://www.cdc.gov/osi/goals/SIHPGPostcard.pdf).

Additional Information. Please access these Web sites via the online version of this summary at http://dx.doi.org/10.1371/journal.pmed.0050066.

- A study by Nancy Krieger and colleagues, published in *PLoS Medicine* in February 2008, documented a similar "fall and rise" in health inequities. Krieger and colleagues reported that the difference in health between rich and poor and between different racial/ethnic groups, as measured by rates of dying young and of infant deaths, shrank in the US from 1966 to 1980 then widened from 1980 to 2002
- Murray and colleagues, in a 2006 *PLoS Medicine* article, calculated US mortality rates according to "race-county" units and divided into the "eight Americas," and found disparities in life expectancy across them
- The US Centers for Disease Control has an Office of Minority Health and Health Disparities. The office "aims to accelerate CDC's health impact in the US population and to eliminate health disparities for vulnerable populations as defined by race/ethnicity, socioeconomic status, geography, gender, age, disability status, risk status related to sex and gender, and among other populations identified to be at-risk for health disparities"
- Wikipedia has a chapter on health disparities (note that Wikipedia is a free online encyclopedia that anyone can edit; available in several languages)
- In 2001 the US Agency for Healthcare Research and Quality sponsored a workshop on "strategies to reduce health disparities"