

Widening Rural–Urban Disparities in All-Cause Mortality and Mortality from Major Causes of Death in the USA, 1969–2009

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ABSTRACT *This study examined trends in rural–urban disparities in all-cause and cause-specific mortality in the USA between 1969 and 2009. A rural–urban continuum measure was linked to county-level mortality data. Age-adjusted death rates were calculated by sex, race, cause-of-death, area-poverty, and urbanization level for 13 time periods between 1969 and 2009. Cause-of-death decomposition and log-linear and Poisson regression were used to analyze rural–urban differentials. Mortality rates increased with increasing levels of rurality overall and for non-Hispanic whites, blacks, and American Indians/Alaska Natives. Despite the declining mortality trends, mortality risks for both males and females and for blacks and whites have been increasingly higher in non-metropolitan than metropolitan areas, particularly since 1990. In 2005–2009, mortality rates varied from 391.9 per 100,000 population for Asians/Pacific Islanders in rural areas to 1,063.2 for blacks in small-urban towns. Poverty gradients were steeper in rural areas, which maintained higher mortality than urban areas after adjustment for poverty level. Poor blacks in non-metropolitan areas experienced two to three times higher all-cause and premature mortality risks than affluent blacks and whites in metropolitan areas. Disparities widened over time; excess mortality from all causes combined and from several major causes of death in non-metropolitan areas was greater in 2005–2009 than in 1990–1992. Causes of death contributing most to the increasing rural–urban disparity and higher rural mortality include heart disease, unintentional injuries, COPD, lung cancer, stroke, suicide, diabetes, nephritis, pneumonial/influenza, cirrhosis, and Alzheimer’s disease. Residents in metropolitan areas experienced larger mortality reductions during the past four decades than non-metropolitan residents, contributing to the widening gap.*

KEYWORDS *Mortality, Cause of death, Rural–urban, Metropolitan, Decomposition, Race, Poverty, Inequality, Trend, USA*

INTRODUCTION

Geographical inequalities in health have long represented an important area of public health research in the USA.^{1–6} Mortality data for urban and rural areas have been available for several decades in the USA although mortality rates have been published infrequently due to the lack of appropriate denominator or population statistics.^{1–3} Reduction of health inequalities, including those between rural and

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urban areas, has been an important policy goal for the USA since 1990, as specified in its national health initiative, *Healthy People*.⁷⁻⁹

Long-term trends and contemporary patterns in all-cause mortality and mortality from major causes of death are routinely analyzed by sex and broad racial/ethnic groups in the USA.^{1,10-12} Many US studies have also reported mortality differentials according to socioeconomic position or area-based deprivation level.^{4-6,13-15} Rural-urban or urbanization patterns in mortality have been analyzed in detail for selected causes of death, such as suicide, heart disease, HIV/AIDS, all cancers combined, and lung, colorectal, prostate, breast, and cervical cancers.¹⁶⁻²² To our knowledge, comprehensive efforts have not yet been undertaken to examine US mortality trends and patterns for all-cause mortality and mortality from major causes of death according to urbanization level in a temporal fashion. It is important to know the magnitude and causes of mortality disparities between rural and urban areas for the purposes of social planning and public health decision making. Moreover, temporal analysis of rural-urban differentials not only allows us to track progress toward reducing health disparities between geographical areas, but it also provides important insights into the role of health-policy interventions and of behavioral and healthcare factors such as smoking, obesity, physical activity, and differential access to health services, as well as of changing socioeconomic conditions.^{6,17,18} Such an analysis is also important for allocating critical social and public health resources towards those in rural or urban areas who may be at higher risk of mortality from major chronic conditions and injuries.^{6,17-19}

The aim of our study is to examine changes in the extent of rural-urban disparities in US mortality between 1969 and 2009. We use a county-based rural-urban variable linked to national mortality data to examine the extent to which differences in all-cause mortality and mortality from major causes of death among US men and women in metropolitan and non-metropolitan areas have changed during the past four decades. We analyze mortality patterns by urbanization level, after adjusting for age, race, sex, and area-poverty rates. We also decompose rural-urban disparities in all-cause mortality attributable to excess rural mortality from selected major causes of death.

METHODS

To analyze temporal rural-urban inequalities in US mortality, we used the national vital statistics mortality database.^{1,10-12,23} Since the national mortality database does not allow direct computation of mortality rates for people in rural and urban areas, the 1974, 1983, 1993, and 2003 rural-urban continuum variables were linked to the age-sex-race-county-specific mortality statistics from 1969-1980, 1981-1989, 1990-1998, and 1999-2009, respectively, to derive mortality estimates.^{16-19,24-26}

The rural-urban continuum variable, developed by the US Department of Agriculture, classifies all US counties into nine distinct groups according to decreasing urbanization levels or increasing levels of rurality, based on the population size of the counties and their proximity to metropolitan areas.^{17-19,24-27} This rural-urban variable defines the degree of urban (city-like) or rural character of a particular geographic area. The variable further subdivides non-metropolitan areas into small-urban towns and completely rural areas in terms of population size, commuting flows, and the degree to which they are socioeconomically integrated with the larger metropolitan areas.^{1,24-26} The nine categories are defined as follows: (1) most urban = counties in metropolitan areas of 1 million population or more; (2) 2nd most urban = counties in metropolitan

areas of 250,000–1,000,000 population; (3) 3rd most urban = counties in metropolitan areas of less than 250,000 population; (4) 4th most urban = urban non-metropolitan counties with population of 20,000 or more, adjacent to a metropolitan area; (5) 5th most urban = urban non-metropolitan counties with population of 20,000 or more, not adjacent to a metropolitan area; (6) 6th most urban = urban non-metropolitan counties with population of 2,500–19,999, adjacent to a metropolitan area; (7) 7th most urban = urban non-metropolitan counties with population of 2,500–19,999, not adjacent to a metropolitan area; (8) 2nd most rural = rural counties with a population of <2,500, adjacent to a metropolitan area; and (9) most rural = rural counties with a population of <2,500, not adjacent to a metropolitan area.^{14–16} For computing mortality rates, we collapsed the nine rural–urban continuum categories into five groups: large metropolitan county group (code 1), medium metropolitan county group (code 2), small metropolitan county group (code 3), urban non-metropolitan county group (codes 4–7), and rural non-metropolitan county group (codes 8 and 9). The number of counties in these five rural–urban groups were 414, 325, 351, 1,381, and 670, respectively.^{19,26,27} The five rural–urban groups accounted for 53.4, 20.1, 10.0, 14.8, and 1.7 % of the total US population in 2010, respectively.²⁶ The broad metropolitan category included large metropolitan counties with population ≥ 1 million and smaller metropolitan counties of population <250,000. The non-metropolitan category included small-urban towns of population <20,000 and rural towns with a population of <2,500, which may or may not be adjacent to a metropolitan area.^{17–19,25,26} Although health and socioeconomic conditions do differ across the five rural–urban groups, the long-term mortality trends between the broader metropolitan and non-metropolitan categories are taken to depict rural–urban trends over time.^{17–19,25,26}

Mortality rates were computed for 12 3-year time periods: 1969–1971, 1972–1974, ..., 2002–2004 and 1 5-year period, 2005–2009. These time periods were used due to the availability and confidential restrictions of county-level mortality data.^{11,23} Age–sex–race–county-specific deaths for the 13 time periods were obtained using the national mortality database,^{10,11,23} whereas age–sex–race–county-specific population estimates for the same time periods, developed by the US Census Bureau, served as denominators for computing mortality rates.^{11,28–30} Each of the 3,141 counties in the mortality database was assigned one of the five rural–urban continuum categories or one of the two metropolitan–nonmetropolitan categories. Mortality rates were age-adjusted by the direct method using the age composition of the 2000 US population as the standard and age-specific mortality rates for 19 age groups: <1, 1–4, 5–9, ..., 80–84, 85+ years.^{11,17–20}

Since metropolitan and non-metropolitan areas differ substantially in their socioeconomic and demographic characteristics,^{17,26,30} we examined rural–urban differences in mortality by stratifying analyses according to area-poverty level and race for 1990–1992 and 2005–2009. For income-specific analyses, we linked county-level poverty data from the 1990 and 2000 censuses with county-level mortality statistics for 1990–1992 and 2005–2009, respectively.^{28,29} Five area-poverty groups were used: <5.00 % (i.e., less than 5 % of the population below the poverty line in a county), 5.00–9.99 %, 10.00–14.99 %, 15.00–19.99 %, and ≥ 20 %.

Log-linear regression models were used to estimate annual rates of change in mortality trends in metropolitan and non-metropolitan areas.^{5,6,17,18} Specifically, the logarithm of the mortality rates were modeled as a linear function of time (calendar year), which yielded annual exponential rates of decline in mortality rates.^{5,6,17,18} Metropolitan–nonmetropolitan disparities in mortality were described by rate ratios or relative risks and rate differences, which were tested for statistical significance at

the 0.05 level.¹⁷⁻¹⁹ Absolute rate differences in all-cause mortality between metropolitan and non-metropolitan areas were decomposed into contributions by major underlying causes of death. Additionally, all-cause mortality was modeled as a function of age distribution, sex, race, poverty level, and rural-urban continuum. Poisson regression models, as estimated by the SAS GENMOD procedure, were used to derive relative risks of all-cause mortality and premature mortality (under age 75 years) by urbanization level after adjusting for poverty levels.³¹

RESULTS

Figure 1 presents sex- and race-specific all-cause mortality trends in metropolitan and non-metropolitan areas from 1969 to 2009. Despite the declining mortality trends, mortality risks for both males and females and for blacks and whites have been increasingly higher in non-metropolitan than in metropolitan areas, particularly since 1990. Between 1969-1971 and 2005-2009, residents of metropolitan areas experienced faster declines in mortality than those of non-metropolitan areas, which contributed to the widening gap in mortality. This pattern held for both men and women and for whites and blacks. During 1969-2009, all-cause mortality among men in metropolitan areas decreased at 1.40 % per year, significantly faster than the annual rate of decline of 1.09 % for men in non-metropolitan areas. The average annual mortality declines for women in metropolitan and non-metropolitan areas were 0.98 and 0.68 %, respectively. Mortality among blacks declined at an annual rate of 1.01 % in metropolitan areas and at a rate of 0.80 % in non-metropolitan areas. For whites, the corresponding rates of decline were 1.18 and 0.91 %. Inequalities in mortality between non-metropolitan blacks and metropolitan whites were large and increased over time, from a relative risk of 1.28 in 1969-1971 to 1.43 in 2005-2009.

Mortality rates increased with increasing levels of rurality for the total population and for non-Hispanic whites, blacks, and American Indians/Alaska Natives (Fig. 2). In 2005-2009, mortality rates varied from a low of 391.9 per 100,000 population for Asians/Pacific Islanders in rural areas to a high of 1,063.2 for blacks in small-urban towns. Non-Hispanic whites in rural areas had 13 % higher mortality (RR=1.13; 95 % CI=1.13-1.14), blacks in rural areas had 8 % higher mortality (RR=1.08; 95 % CI=1.06-1.09), and American Indians/Alaska Natives in rural areas 162 % higher mortality (RR=2.62; 95 % CI=2.54-2.71) than their counterparts in large metropolitan areas. No consistent relationship between urbanization level and mortality was found for Asians/Pacific Islanders and Hispanics. Racial/ethnic and rural-urban patterns in mortality were similar for males and females, with females and males in rural areas having 13 and 16 % higher mortality than their counterparts in large metropolitan areas, respectively. Among men, blacks in small-urban towns and small-metropolitan areas had the highest mortality rates, whereas American Indians/Alaska Natives in rural areas had the highest mortality rates among women (Fig. 2).

Area-poverty gradients were steeper in rural areas, which maintained higher mortality than urban areas after adjusting for poverty level (Tables 1 and 2). Both urbanization and poverty level contributed significantly to variations in all-cause and premature mortality in 2005-2009. Regardless of poverty level, rural non-metropolitan residents experienced 16 % higher all-cause mortality and 26 % higher premature mortality than residents of large metropolitan areas (Table 2). Rural-urban disparities in mortality were more marked when race and poverty were considered jointly. Blacks

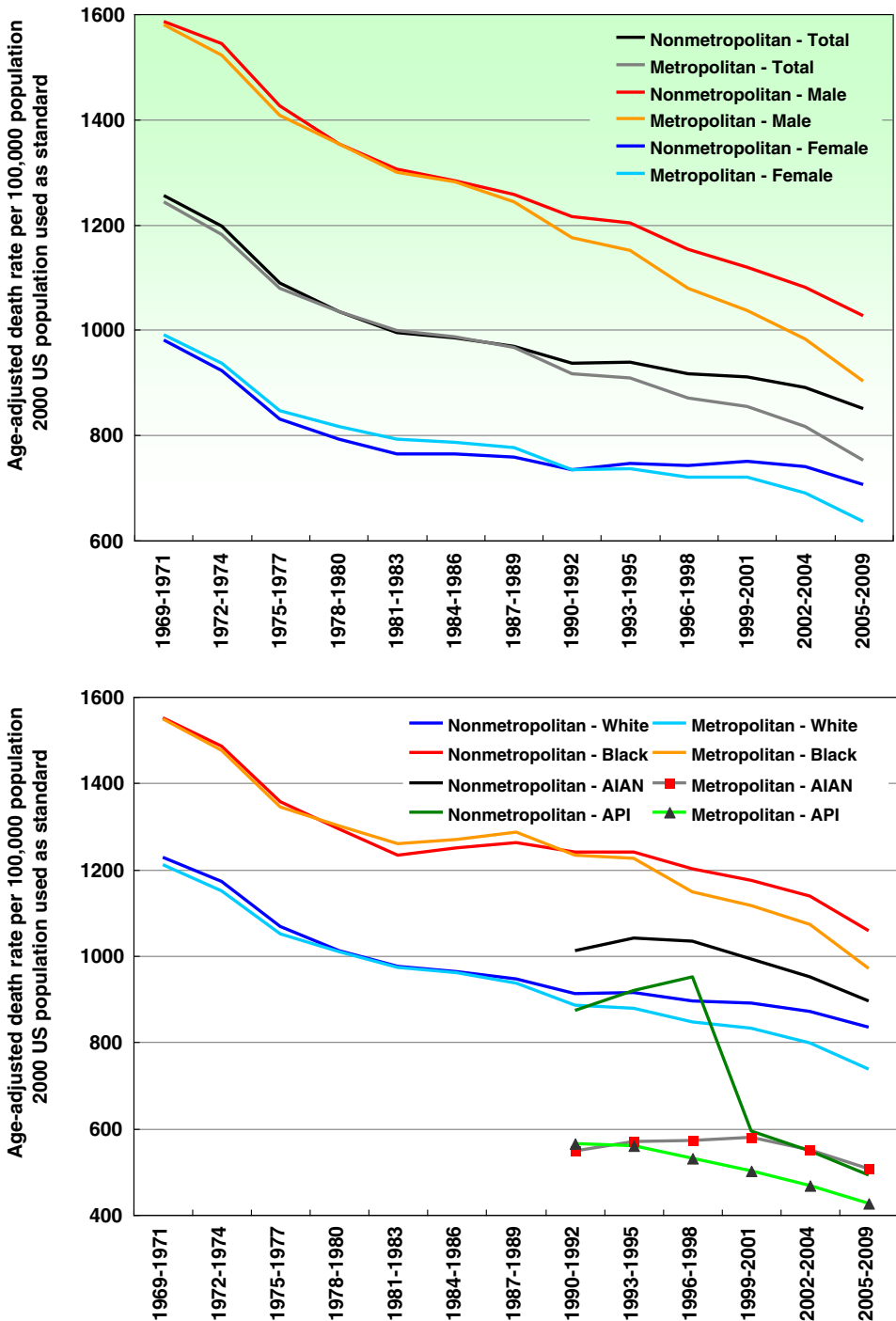


FIGURE 1. All-cause mortality rates in metropolitan and non-metropolitan areas by sex and race, USA, 1969–2009 (API Asians and Pacific Islanders, AIAN American Indians and Alaska Natives).

in poor non-metropolitan areas (poverty rate $\geq 20\%$) had the highest all-cause and premature mortality rates, two to three times higher than those for whites and blacks in affluent metropolitan areas (poverty rate $< 5\%$) (data not shown).

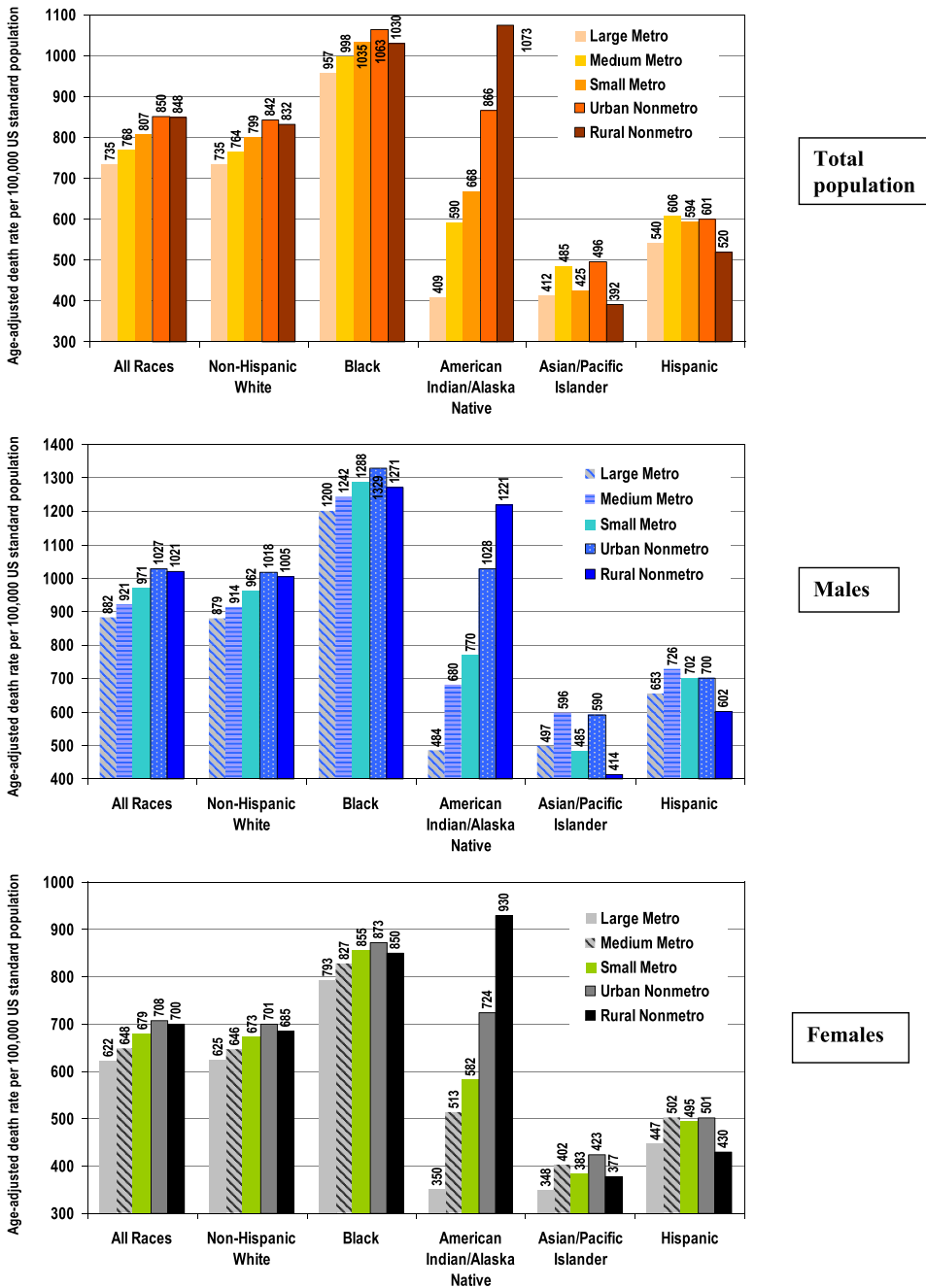


FIGURE 2. All-cause mortality rates by race/ethnicity and urbanization level, USA, 2005–2009.

Rural-urban disparities in age-specific mortality, all-cause mortality, and mortality from several major causes of death widened between 1990 and 2009 (Table 3). Compared to metropolitan areas, the overall all-cause mortality in non-metropolitan areas was 2 % higher in 1990–1992 but 13 % higher in 2005–2009. Disparities widened for mortality in every age group, particularly for children and those aged 25–44. Infant mortality was 11 % higher and child mortality 41 %

TABLE 1 Area poverty gradients in all-cause and premature mortality (under age 75 years) rates and adjusted relative risks (RR) of mortality derived from Poisson regression models for metropolitan and non-metropolitan areas of the USA, 2005–2009

	Metropolitan areas				Non-metropolitan areas			
	Age-adjusted		Age-sex-race-adjusted		Age-adjusted		Age-sex-race-adjusted	
	Mortality rate	SE	RR	95 % CI	Mortality rate	SE	RR	95 % CI
All-cause mortality								
Area poverty rate								
<5 %	679.42	0.94	1.00	Reference	681.57	6.56	1.00	Reference
5–9.99 %	717.46	0.41	1.10	1.10–1.11	759.25	1.05	1.11	1.09–1.13
10–14.99 %	773.64	0.40	1.18	1.18–1.18	826.93	0.85	1.21	1.19–1.23
15–19.99 %	793.96	0.66	1.20	1.20–1.21	897.21	1.14	1.30	1.28–1.33
≥20 %	789.48	1.00	1.16	1.16–1.17	966.92	1.46	1.37	1.35–1.40
Premature mortality (<75 years)								
Area poverty rate								
<5 %	261.31	0.57	1.00	Reference	268.86	4.48	1.00	Reference
5–9.99 %	313.16	0.28	1.26	1.25–1.26	333.99	0.75	1.30	1.26–1.34
10–14.99 %	369.01	0.28	1.46	1.46–1.47	391.67	0.63	1.56	1.51–1.61
15–19.99 %	391.10	0.48	1.52	1.51–1.53	457.89	0.87	1.80	1.74–1.86
≥20 %	410.61	0.74	1.53	1.53–1.54	524.66	1.12	1.96	1.90–2.03

Metropolitan areas consist of large metro counties of a million people or more and smaller metro counties of population <250,000. Non-metropolitan areas consist of small urban towns with a population <20,000 and rural towns with a population <2,500. Mortality rates are per 100,000 population and age-adjusted to the 2000 US standard population. For computing relative risks of mortality, area poverty rate <5 % was treated as the reference category. Relative risks were adjusted by Poisson regression for age, sex, and race

TABLE 2 Urbanization and area-poverty gradients in all-cause and premature mortality (under age 75 years) rates and adjusted relative risks (RR) of mortality derived from Poisson regression models, USA, 2005–2009

	All-cause mortality				Premature mortality (<75 years)			
	Age-adjusted		Covariate-adjusted		Age-adjusted		Covariate-adjusted	
	Mortality rate	SE	RR	95 % CI	Mortality rate	SE	RR	95 % CI
Urbanization level								
Large metro county	734.66	0.31	1.00	Reference	337.16	0.21	1.00	Reference
Medium metro county	768.00	0.49	1.06	1.06–1.06	361.19	0.35	1.10	1.09–1.11
Small metro county	806.57	0.71	1.09	1.09–1.10	380.58	0.51	1.14	1.13–1.14
Urban nonmetro county	850.05	0.57	1.16	1.16–1.17	414.37	0.42	1.25	1.25–1.25
Rural nonmetro county	848.21	1.59	1.16	1.15–1.16	419.70	1.22	1.26	1.26–1.27
Area poverty rate								
<5 %	679.39	0.93	1.00	Reference	261.40	0.57	1.00	Reference
5–9.99 %	723.12	0.38	1.08	1.07–1.08	315.79	0.26	1.20	1.19–1.21
10–14.99 %	783.63	0.36	1.15	1.15–1.15	372.87	0.26	1.40	1.40–1.41
15–19.99 %	821.93	0.57	1.19	1.19–1.19	408.32	0.42	1.50	1.49–1.50
≥20 %	853.39	0.83	1.19	1.19–1.19	450.79	0.62	1.56	1.55–1.56
Race/ethnicity								
White	757.42	0.24	1.73	1.72–1.73	343.73	0.17	1.66	1.66–1.67
Black	981.27	0.84	2.23	2.23–2.24	545.16	0.58	2.52	2.51–2.54
API and AIAN	464.67	0.87	1.00	Reference	211.83	0.53	1.00	Reference
Sex								
Male	925.83	0.38	1.35	1.34–1.35	449.09	0.25	1.59	1.59–1.59
Female	648.44	0.27	1.00	Reference	277.20	0.19	1.00	Reference

Mortality rates are per 100,000 population and age-adjusted to the 2000 US standard population. Relative risks were adjusted by Poisson regression for age, sex, area poverty, and urbanization level
 API Asians and Pacific Islanders, AIAN American Indians and Alaska Natives

TABLE 3 All-cause and cause-specific mortality rates per 100,000 population (age-adjusted to the 2000 US standard population) for metropolitan and non-metropolitan areas of the USA, 1990–1992 and 2005–2009

Age and cause of death	2005–2009		1990–1992		2005–2009		1990–1992	
	Metropolitan area	Non-metropolitan area	Metropolitan area	Non-metropolitan area	Rate ratio ^a	95 % CI	Rate ratio ^a	95 % CI
All ages and all causes	751.67	849.58	915.78	936.56	1.13*	1.13–1.13	1.02*	1.02–1.02
Age group								
Age under 1 year (infant mortality) ^b	654.63	725.15	918.65	911.54	1.11*	1.09–1.12	0.99	0.98–1.01
Age group 1–14 years	17.40	24.48	28.30	34.04	1.41*	1.38–1.44	1.20*	1.18–1.23
Age group 15–24 years	73.50	94.48	94.00	109.51	1.29*	1.27–1.30	1.17*	1.15–1.18
Age group 25–44 years	141.82	193.10	188.83	174.46	1.36*	1.35–1.37	0.92*	0.92–0.93
Age group 45–64 years	586.99	691.09	728.20	753.11	1.18*	1.17–1.18	1.03*	1.03–1.04
Age group 65+ years	4,401.58	4,830.33	5272.31	5,401.52	1.10*	1.10–1.10	1.02*	1.02–1.03
Cause of death								
Cardiovascular diseases (CVD)	248.30	280.22	394.21	412.93	1.13*	1.13–1.13	1.05*	1.04–1.05
Heart disease	190.17	213.64	310.42	319.77	1.12*	1.12–1.13	1.03*	1.03–1.03
Stroke	41.13	48.35	61.58	68.93	1.18*	1.17–1.18	1.12*	1.11–1.13
Atherosclerosis	2.67	2.91	7.54	9.05	1.09*	1.07–1.11	1.20*	1.18–1.22
All malignant cancers	175.90	190.50	215.56	211.21	1.08*	1.08–1.09	0.98*	0.98–0.98
Lung and bronchus	49.00	57.51	58.84	59.35	1.17*	1.17–1.18	1.01*	1.01–1.02
Colorectal	16.34	18.18	24.31	23.42	1.11*	1.10–1.12	0.96*	0.95–0.97
Prostate	23.32	24.61	38.93	39.34	1.06*	1.04–1.07	1.01	1.00–1.03
Breast (female)	23.14	22.56	33.22	30.03	0.97*	0.96–0.99	0.90*	0.89–0.92
Cervical	2.33	2.70	3.50	3.79	1.16*	1.02–1.20	1.08*	1.04–1.13
Melanoma of the skin	2.67	3.01	2.70	2.79	1.13*	1.10–1.15	1.03*	1.01–1.06
Liver and Intrahepatic bile duct	5.60	4.93	3.83	3.42	0.88*	0.87–0.90	0.89*	0.86–0.92
Esophagus	4.21	4.73	4.25	3.76	1.12*	1.10–1.14	0.88*	0.86–0.91
Stomach	3.73	3.13	6.17	5.04	0.84*	0.82–0.86	0.82*	0.80–0.84
Pancreatic	10.86	10.81	10.82	10.31	1.00	0.98–1.01	0.95*	0.94–0.97

TABLE 3 (Continued)

Age and cause of death	2005-2009		1990-1992		2005-2009		1990-1992	
	Metropolitan area	Non-metropolitan area	Metropolitan area	Non-metropolitan area	Rate ratio ^a	95 % CI	Rate ratio ^a	95 % CI
Uterine	4.22	4.01	4.25	4.21	0.95*	0.93-0.98	0.99	0.95-1.03
Ovarian	8.24	8.23	9.49	9.23	1.00	0.98-1.02	0.97*	0.95-0.99
Bladder	4.35	4.45	4.54	4.21	1.02*	1.01-1.04	0.93*	0.90-0.95
Kidney	3.89	4.50	4.21	4.43	1.16*	1.13-1.18	1.05*	1.02-1.08
Brain	4.20	4.63	4.83	5.12	1.10*	1.08-1.12	1.06*	1.03-1.09
Non-Hodgkin's lymphoma	6.49	6.83	8.16	7.87	1.05*	1.04-1.07	0.96*	0.95-0.98
Myeloma	3.41	3.46	3.83	3.78	1.01	0.99-1.04	0.99	0.96-1.02
Leukemia	7.01	7.47	7.90	8.25	1.07*	1.05-1.08	1.04*	1.02-1.06
Chronic lower respiratory disease/COPD	40.25	50.62	36.94	39.71	1.26*	1.25-1.26	1.07*	1.07-1.08
Diabetes mellitus	21.97	25.64	20.44	21.34	1.17*	1.16-1.18	1.04*	1.03-1.06
Alzheimer's disease	22.91	25.37	6.17	6.81	1.11*	1.10-1.12	1.10*	1.08-1.13
Pneumonia and influenza	17.05	19.72	34.38	35.65	1.16*	1.15-1.17	1.04*	1.03-1.05
Nephritis/kidney diseases	14.17	16.75	9.05	10.01	1.18*	1.17-1.19	1.11*	1.09-1.13
Chronic liver disease and cirrhosis	8.93	9.70	11.19	9.04	1.09*	1.07-1.10	0.81*	0.79-0.82
Infectious diseases excluding HIV/AIDS	17.65	17.42	13.60	11.37	0.99*	0.98-0.99	0.84*	0.82-0.85
HIV/AIDS								
HIV/AIDS	4.01	1.95	13.66	3.15	0.49*	0.47-0.50	0.23*	0.22-0.24
Maternal/pregnancy-related causes ^c	14.46	15.39	8.35	7.67	1.06	0.96-1.17	0.92	0.77-1.07
Congenital anomalies (infant mortality) ^b	130.39	147.95	192.34	209.01	1.13*	1.10-1.17	1.09*	1.05-1.12
Perinatal conditions (infant mortality) ^b	334.03	316.53	426.91	360.92	0.95*	0.93-0.97	0.85*	0.83-0.87
SIDS/related conditions (infant mortality) ^b	76.91	119.94	150.38	174.51	1.56*	1.50-1.62	1.16*	1.12-1.20

Unintentional injuries	36.08	54.20	32.55	48.62	1.50*	1.49-1.51	1.49*	1.48-1.51
Suicide	10.73	14.35	11.88	13.62	1.34*	1.32-1.35	1.15*	1.13-1.17
Homicide	6.35	4.63	10.43	6.39	0.73*	0.72-0.74	0.61*	0.60-0.63

Source: Data derived from the US National Vital Statistics System, 1990-2009

CI confidence interval

* $p < 0.05$, mortality rate ratios were statistically significantly different from 1 at this level

^aRatio of mortality rate for non-metropolitan areas to that for metropolitan areas

^bInfant mortality rate per 100,000 live births

^cMaternal mortality rate per 100,000 live births

TABLE 4 Decomposition of metropolitan and non-metropolitan age-adjusted mortality rate differentials into major causes of death, USA, 1990-1992 and 2005-2009

Cause of death	2005-2009		1990-1992		2005-2009		1990-1992		2005-2009		1990-1992	
	Absolute rate difference	Nonmetropolitan - Metropolitan	Absolute rate difference	Nonmetropolitan - Metropolitan	% contribution by each cause	Nonmetropolitan - Metropolitan	Absolute rate difference	Nonmetropolitan - Metropolitan	Absolute rate difference	Nonmetropolitan - Metropolitan	% contribution by each cause	Nonmetropolitan - Metropolitan
All causes of death	97.91	20.78	100.0	100.0	100.0	100.0	287.50	205.49	100.0	100.0	100.0	100.0
Cardiovascular diseases (CVD)	31.92	18.72	32.6	90.1	90.1	100.34	105.64	100.34	36.7	36.7	48.8	48.8
Heart disease	23.47	9.35	24.0	45.0	45.0	86.69	86.69	78.67	30.2	30.2	38.3	38.3
Stroke	7.22	7.35	7.4	35.4	35.4	14.65	14.65	18.46	5.1	5.1	9.0	9.0
All malignant cancers	14.60	-4.35	14.9	-20.9	-20.9	35.30	35.30	10.55	12.3	12.3	5.1	5.1
Lung and bronchus	8.51	0.51	8.7	2.5	2.5	17.74	10.39	10.39	6.2	6.2	5.1	5.1
Colorectal	1.84	-0.89	1.9	-4.3	-4.3	4.50	4.50	-3.20	1.6	1.6	-1.6	-1.6
Chronic lower respiratory disease/COPD	10.37	2.77	10.6	13.3	13.3	17.49	17.49	7.18	6.1	6.1	3.5	3.5
Diabetes mellitus	3.67	0.90	3.7	4.3	4.3	16.81	16.81	7.53	5.8	5.8	3.7	3.7
Alzheimer's disease	2.46	0.64	2.5	3.1	3.1	2.69	2.69	-1.42	0.9	0.9	-0.7	-0.7
Pneumonia and influenza	2.67	1.27	2.7	6.1	6.1	8.02	8.02	3.42	2.8	2.8	1.7	1.7
Nephritis/kidney diseases	2.58	0.96	2.6	4.6	4.6	8.91	8.91	4.52	3.1	3.1	2.2	2.2
Chronic liver disease and cirrhosis	0.77	-2.15	0.8	-10.3	-10.3	6.47	6.47	4.05	2.3	2.3	2.0	2.0

Infectious diseases excluding HIV/AIDS	-0.23	-2.23	-0.2	-10.7	7.83	1.78	2.7	0.9
HIV/AIDS	-2.06	-10.51	-2.1	-50.6	3.39	-0.27	1.2	-0.1
Congenital anomalies (all ages)	0.62	0.30	0.6	1.4	1.41	1.61	0.5	0.8
Perinatal conditions (all ages)	-0.24	-0.93	-0.2	-4.5	2.02	2.55	0.7	1.2
Symptoms/signs/ill- defined conditions (all ages)	1.74	0.84	1.8	4.0	5.69	3.37	2.0	1.6
Unintentional injuries	18.12	16.07	18.5	77.3	38.48	34.00	13.4	16.5
Suicide	3.62	1.74	3.7	8.4	6.93	3.69	2.4	1.8
Homicide	-1.72	-4.04	-1.8	-19.4	4.61	9.73	1.6	4.7
All other causes	9.02	0.78	9.3	3.8	15.81	12.86	5.5	6.3

Affluent area = county poverty rate <5.00 %; Poor area = county poverty rate \geq 20.00 %. All mortality rate differences were statistically significantly different from 0 at $p < 0.05$. Source: Data derived from the US National Vital Statistics System, 1990–2009

TABLE 5 All-cause and cause-specific mortality rates per 100,000 population (age-adjusted to the 2000 US standard population) for affluent metropolitan and poor non-metropolitan areas of the USA, 1990-1992 and 2005-2009

Age and cause of death	2005-2009		1990-1992		2005-2009		1990-1992	
	Affluent metro area	Poor non-metro area	Affluent metro area	Poor non-metro area	Rate ratio ^a	95 % CI	Rate ratio ^a	95 % CI
All ages and all causes	679.42	966.92	834.33	1,039.82	1.42*	1.42-1.43	1.25*	1.24-1.25
Age group								
Age under 1 year (infant mortality) ^b	484.00	905.20	645.02	1,083.01	1.87*	1.80-1.94	1.68*	1.62-1.74
Age group 1-14 years	11.99	30.84	19.10	41.21	2.57*	2.42-2.72	2.16*	2.04-2.28
Age group 15-24 years	59.87	108.18	66.03	124.16	1.81*	1.75-1.87	1.88*	1.81-1.95
Age group 25-44 years	89.84	270.44	115.80	223.82	3.01*	2.96-3.06	1.93*	1.90-1.97
Age group 45-64 years	403.52	897.72	562.12	888.36	2.22*	2.20-2.24	1.58*	1.56-1.60
Age group 65+ years	4,317.09	5,168.41	5,235.58	5,647.80	1.20*	1.19-1.20	1.08*	1.07-1.08
Cause of death								
Cardiovascular diseases (CVD)	217.83	323.47	360.59	460.93	1.48*	1.47-1.50	1.28*	1.27-1.29
Heart disease	163.41	250.10	281.78	360.45	1.53*	1.52-1.54	1.28*	1.27-1.29
Stroke	38.51	53.16	58.59	77.05	1.38*	1.36-1.40	1.32*	1.29-1.34
Atherosclerosis	3.51	2.34	6.21	8.08	0.67*	0.62-0.71	1.30*	1.21-1.39
All malignant cancers	169.39	204.69	210.98	221.53	1.21*	1.20-1.22	1.05*	1.04-1.06
Lung and bronchus	45.63	63.37	54.18	64.57	1.39*	1.37-1.41	1.19*	1.17-1.22
Colorectal	15.71	20.21	25.16	21.96	1.29*	1.25-1.32	0.87*	0.84-0.90
Prostate	22.13	28.89	40.01	42.93	1.31*	1.26-1.35	1.07*	1.02-1.12
Breast (female)	23.06	24.58	34.57	28.58	1.07*	1.03-1.10	0.83*	0.79-0.86
Cervical	1.55	3.77	2.50	5.09	2.43*	2.19-2.68	2.04*	1.79-2.28
Melanoma of the skin	2.98	2.43	2.90	2.31	0.82*	0.76-0.87	0.80*	0.71-0.88
Liver and Intrahepatic bile duct	4.56	5.98	3.45	4.51	1.31*	1.25-1.38	1.31*	1.20-1.42
Esophagus	4.37	4.37	3.85	3.98	1.00	0.95-1.05	1.03	0.95-1.12
Stomach	3.35	4.24	5.75	6.35	1.27*	1.19-1.34	1.10*	1.03-1.18
Pancreatic	10.88	11.16	10.64	11.20	1.03	0.99-1.06	1.05*	1.01-1.11
Uterine	4.16	4.01	3.94	4.31	0.96	0.89-1.04	1.09	0.98-1.21

Ovarian	8.49	7.73	10.05	8.12	0.91*	0.86-0.96	0.81*	0.75-0.87
Bladder	4.51	3.96	4.69	3.60	0.88*	0.83-0.93	0.77*	0.70-0.83
Kidney	3.80	4.85	4.24	4.41	1.28*	1.21-1.35	1.04	0.96-1.12
Brain	4.43	4.48	4.93	4.94	1.01	0.96-1.07	1.00	0.92-1.07
Non-Hodgkin's lymphoma	6.70	6.35	8.32	6.82	0.95*	0.90-0.99	0.82*	0.77-0.87
Myeloma	3.41	3.57	3.91	4.03	1.05	0.98-1.11	1.03	0.94-1.12
Leukemia	7.23	7.11	7.89	8.24	0.98	0.94-1.03	1.04	0.98-1.11
Chronic lower respiratory disease/COPD	34.83	52.32	33.07	40.25	1.50*	1.48-1.53	1.22*	1.18-1.25
Diabetes mellitus	16.77	33.58	18.31	25.84	2.00*	1.96-2.05	1.41*	1.36-1.46
Alzheimer's disease	22.01	24.70	6.91	5.49	1.12*	1.10-1.15	0.79*	0.74-0.85
Pneumonia and influenza	15.12	23.14	33.34	36.76	1.53*	1.49-1.57	1.10*	1.07-1.14
Nephritis/kidney diseases	14.53	23.44	8.91	13.43	1.61*	1.57-1.66	1.51*	1.43-1.59
Chronic liver disease and cirrhosis	5.81	12.28	7.30	11.35	2.11*	2.03-2.19	1.55*	1.47-1.64
Infectious diseases excluding HIV/AIDS	16.61	24.44	13.75	15.53	1.47*	1.43-1.59	1.13*	1.08-1.18
HIV/AIDS	0.92	4.31	4.15	3.88	4.68*	4.30-5.07	0.93*	0.86-1.01
Maternal/pregnancy-related causes ^c	11.86	22.75	3.11	11.10	1.92*	1.47-2.37	3.57*	1.63-5.51
Congenital anomalies (infant mortality) ^b	110.32	164.90	159.15	247.17	1.49*	1.37-1.62	1.55*	1.42-1.69
Perinatal conditions (infant mortality) ^b	255.45	400.00	284.91	466.48	1.57*	1.48-1.65	1.64*	1.53-1.74
SIDS/related conditions (infant mortality) ^b	42.02	155.55	87.53	202.32	3.70*	3.30-4.10	2.31*	2.06-2.57
Unintentional injuries	28.41	66.89	26.73	60.73	2.35*	2.31-2.40	2.27*	2.21-2.33
Suicide	9.05	13.66	9.40	13.09	1.51*	1.46-1.56	1.39*	1.33-1.46
Homicide	1.97	8.90	2.63	12.36	4.52*	4.25-4.79	4.70*	4.37-5.02

Affluent area = poverty rate < 5.00 %. Poor area = poverty rate \geq 20.00 %. Source: Data derived from the US National Vital Statistics System, 1990-2009

* $p < 0.05$, mortality rate ratios were statistically significantly different from 1 at this level

^aRatio of mortality rate for poor non-metropolitan areas to that for affluent metropolitan areas

^bInfant mortality rate per 100,000 live births

^cMaternal mortality rate per 100,000 live births

higher in non-metropolitan than metropolitan areas. Non-metropolitan residents aged 25–44 years had 8 % lower mortality in 1990–1992 but 36 % higher mortality in 2005–2009. Relative risk of mortality in 2005–2009 was significantly higher in non-metropolitan than metropolitan areas from heart disease, stroke, lung, colorectal, prostate, cervical, esophageal, kidney, and brain cancers, melanoma, leukemia, non-Hodgkin's lymphoma, COPD, diabetes, pneumonia/influenza, nephritis, liver cirrhosis, Alzheimer's disease, unintentional injuries, suicide, SIDS, and birth defects. Relative risk of mortality in non-metropolitan areas increased significantly between 1990 and 2007 from 1.05 to 1.13 for CVD, from 1.01 to 1.17 for lung cancer, from 0.96 to 1.11 for colorectal cancer, from 1.01 to 1.06 for prostate cancer, from 1.07 to 1.26 for COPD, from 1.04 to 1.17 for diabetes, from 1.04 to 1.16 for pneumonia/influenza, from 1.11 to 1.18 for nephritis, from 0.81 to 1.09 for liver cirrhosis, from 1.16 to 1.56 for SIDS, and from 1.15 to 1.34 for suicide (Table 3). The decomposition of the absolute mortality-rate differences in 2005–2009 in Table 4 indicates that the causes of death contributing most to the excess mortality in non-metropolitan areas include heart disease (24.0 %), unintentional injuries (18.5 %), COPD (10.6 %), lung cancer (8.7 %), stroke (7.4 %), diabetes (3.7 %), suicide (3.7 %), pneumonia/influenza (2.7 %), kidney diseases (2.6 %), Alzheimer's (2.5 %), and colorectal cancer (1.9 %). Relative contributions of all cancers combined, lung and colorectal cancers, and liver cirrhosis to excess rural mortality increased markedly between 1990–1992 and 2005–2009. Mortality from breast cancer, homicide, perinatal conditions, HIV/AIDS, and other infectious diseases were higher in metropolitan than in non-metropolitan areas and they contributed negatively to the mortality gap in both 1990–1992 and 2005–2009. However, the non-metropolitan advantage in mortality from these causes, particularly HIV/AIDS, diminished between 1990 and 2009 as the declines in mortality from these causes in non-metropolitan areas were slower than those in metropolitan areas.

Differentials in all-cause mortality and age-specific mortality between rural poor and urban rich increased in both absolute and relative terms (Tables 4 and 5). Compared to those in affluent-metropolitan areas, residents of poor-nonmetropolitan areas had 25 % higher mortality in 1990–1992 but 42 % higher mortality in 2005–2009 (Table 5). Infant mortality was 1.9 times higher, child mortality 2.6 times higher, and mortality among those aged 25–44 years 3.0 times higher among the rural poor compared to urban rich in 2005–2009. Not only was the relative risk of mortality significantly higher among the rural poor than urban rich in 2005–2009 but it increased between 1990 and 2009 from CVD, major cancers, diabetes, COPD, cirrhosis, pneumonia/influenza, and infectious diseases. In 2005–2009, the rural poor had 4.7 times higher HIV/AIDS mortality, 4.5 times higher homicide mortality, and 2.4 times higher unintentional-injury mortality than the urban rich. CVD, unintentional injuries, cancer, COPD, and diabetes accounted for 74.3 % of the absolute mortality difference between rural poor and urban rich. The contribution of cancer, COPD, diabetes, cirrhosis, pneumonia/influenza, and infectious diseases to the excess mortality among the rural poor increased between 1990–1992 and 2005–2009 (Table 4).

DISCUSSION

Although mortality rates have declined consistently for all socio-demographic groups in the USA during the past four decades,^{1,10–12} our study shows substantial and increasing rural–urban disparities in all-cause mortality and mortality from several major causes of death over time, as both absolute and relative inequalities in mortality widened between 1969 and 2009. In contrast to the current pattern of

higher rural mortality, the overall US mortality in 1950 was higher in urban and metropolitan areas than in rural and non-metropolitan areas although infant, child, and youth mortality rates were higher in non-metropolitan areas.^{2,3} Consistent with the contemporary pattern, mortality from unintentional injuries (mainly motor-vehicle accidents) and suicide has historically been higher in rural and non-metropolitan areas than in urban areas.^{16,32,33}

The impact of poverty on mortality was substantial, particularly among people in non-metropolitan areas. Poverty levels only partially accounted for rural–urban differences in all-cause and premature mortality, and the rural–urban disparities in mortality were largest in areas with the highest poverty rates. Similar patterns have been observed previously for the USA, with both rural–urban continuum and area deprivation contributing independently to variations in cancer, HIV/AIDS, and youth mortality.^{17–20,27} When both race and area poverty are taken into account, the inequalities are found to be even more marked, with poor blacks in non-metropolitan areas experiencing two to three times higher risks of all-cause and premature mortality than affluent blacks and whites in metropolitan areas. Remarkably, the current mortality experience of rural blacks is similar to the mortality experience of urban and rural whites in the mid-1970s. Excess mortality in rural areas and among the rural poor is primarily driven by higher mortality from CVD, unintentional injuries, cancer, COPD, and diabetes.

With inequalities in all-cause mortality and mortality from several major causes of death on the rise, rural–urban disparities in mortality are not expected to diminish for the foreseeable future. Indeed, if differential mortality trends of the past 20 years were to continue into the future, the non-metropolitan–metropolitan gap in all-cause mortality is expected to widen even further by 2020. Based on our log-linear regression forecast models of trends between 1987 and 2009, relative risk of mortality in non-metropolitan areas, compared to metropolitan areas, was expected to increase in 2020 to 1.21 for the total population, 1.22 for males, and 1.20 for females, respectively (complete forecast data available from authors). Existence of such marked and growing rural–urban disparities in US mortality runs counter to the goals of the national health initiative that calls for further reductions or elimination of health inequalities by 2020.⁷

In addition to the long-term trend analyses of all-cause and cause-specific mortality, decomposition of rural–urban disparities in mortality by cause of death is an important feature of this study. Our decomposition analysis showed that unintentional injuries, CVD, COPD, and lung cancer accounted for 70 % of the overall rural–urban gap in mortality and 62 % of the mortality gap between the rural poor and urban rich in 2005–2009. Interestingly, the rural–urban disparities (as measured by mortality rate ratios and rate differences) in all-cause mortality and mortality from these major causes of death widened between 1990 and 2009. Chronic diseases associated with lifestyle factors such as CVD, respiratory diseases, lung and colorectal cancers, diabetes, and kidney diseases are becoming increasingly important determinants of excess mortality in rural areas and among the rural poor.

Rural–urban patterns in US mortality were generally consistent with those for Canada and Australia, where all-cause mortality and mortality from CVD, diabetes, lung cancer, unintentional injuries (including motor-vehicle accidents), and suicide also tend to be higher in more rural areas.^{34,35} For example, all-cause mortality and CVD mortality in Canada during 1986–1996 were 13 % higher in remote rural areas compared to urban areas—a finding similar to that for the USA.^{34,35} The magnitude of rural–urban disparities was higher in Australia, where residents in very

remote areas had about 50 % higher mortality than their urban counterparts.³⁵ Rural-urban patterns differed for England, where men and women in rural areas had lower all-cause mortality and mortality from lung cancer, respiratory diseases, and heart disease than their urban counterparts in 2002-2004.^{36,37} Deprivation did partly account for excess urban mortality in England, but rural residents maintained lower all-cause, lung cancer, and respiratory-disease mortality.^{36,37}

Our study has limitations. First, although we did use rural-urban continuum codes from four different decades to classify metropolitan and non-metropolitan areas over time, migration or population change could have affected the long term rural-urban mortality trends.^{16,25} Population growth in non-metropolitan areas has been slower than in metropolitan areas for the past four decades and, indeed, more recently, non-metropolitan areas as a whole have experienced population decline, both as a result of a birth deficit (excess of deaths over births) and out-migration.^{16,25} If more affluent residents from rural and non-metropolitan areas migrated to urban and metropolitan areas, that would have increased the rural-urban mortality gap. The return migration of elderly retirees, blue-collar or more disadvantaged workers, and disenchanted urban residents to rural areas would have a similar effect on rural-urban mortality gap.¹⁶ Second, our trend analysis is based on metropolitan and non-metropolitan differences. An analysis using the more detailed five-category rural-urban variable might show a different pattern or greater disparities in mortality according to urbanization level. Third, our socioeconomic measure was county-level poverty rate, which could vary greatly across census tracts within a given county.^{5,6,19,20} Unfortunately, census-tract geocodes are not available in the national mortality database.^{6,11,19,20} Given the compositional heterogeneity of counties, the effect of poverty on mortality reported here is likely to be underestimated in both metropolitan and non-metropolitan areas.^{5,6,19,20}

Widening rural-urban inequalities in mortality shown here may reflect increasing temporal inequalities in socioeconomic conditions between metropolitan and non-metropolitan areas. Rural-urban differences in family income, wealth, poverty, unemployment, and healthcare access have either persisted or increased markedly during the past four decades.^{26,30} The income gap between metropolitan and non-metropolitan areas increased from \$2,892 in 1970 to \$16,842 in 2009.²⁶ The median family income of metropolitan residents in 2009 was \$67,248, compared with \$50,406 for non-metropolitan residents.²⁶ Educational inequalities rose between 1970 and 2009, as 17.3 % of non-metropolitan residents and 29.5 % of metropolitan residents currently report having a college degree. During 1970-2009, the poverty rate remained substantially higher in non-metropolitan areas than in metropolitan areas.^{26,30} The 2009 poverty rate was 17.3 % in non-metropolitan areas and 12.9 % in metropolitan areas.^{26,30}

Rural-urban inequalities in mortality may also reflect inequalities in behavioral and healthcare factors.^{19,26,38} Rural areas have higher smoking and obesity rates and lower access to health services.^{26,38,39} Rural-urban patterns in smoking behavior have changed over the past four decades. In 1976, the smoking prevalence among US adults was 37.8 % for persons living in central cities of metropolitan areas, 36.5 % for persons living outside the central cities in metropolitan areas, and 25.1 % for persons living on rural farms.^{17,40} Contemporary data indicate changing rural-urban patterns, with smoking rates being currently higher among men and women in non-metropolitan areas than in metropolitan areas and smoking prevalence increasing with increasing levels of rurality.^{17,39} In 2010, current smoking prevalence was 16.9 % in large metropolitan areas, 19.7 % in small metropolitan areas, and 26.9 % in non-metropolitan areas.³⁹ Changing urbanization patterns in smoking are also confirmed

by the long-term shifts and reversal of US lung cancer mortality patterns.¹⁷ Until the 1970s, lung cancer mortality was significantly higher in metropolitan areas, whereas it is currently higher in rural and non-metropolitan areas.¹⁷ Obesity prevalence is not only higher in rural areas, but it has increased more rapidly in rural than in urban areas during the past three decades. Between 1976 and 2010, the obesity prevalence in large metropolitan areas rose by 2.8 times to 25.9 %, whereas the prevalence in non-metropolitan areas increased by 3.5 times to 33.2 %.^{39,40}

Rural residents also report significantly higher rates of hypertension, physical inactivity, self-assessed fair/poor health, psychological distress, diabetes, disability, and functional limitation than their urban counterparts.³⁹ Moreover, the rural–urban inequalities in health determinants have increased over time, as rural residents currently fare worse in these health indicators than urban residents, compared to two decades ago.^{39,41} Lower seatbelt use, longer driving distances, differences in motor-vehicle safety, speed limits, and enforcement may contribute to higher motor-vehicle-injury mortality in rural areas.^{27,42}

The health of US children is also less favorable in rural areas than in urban areas.⁴³ Rural children have higher prevalence of obesity, exposure to secondhand smoke, chronic conditions, and obesogenic environment than their urban counterparts.^{43–45} The rural–urban gap in child health, coupled with the increased inequalities in infant, child, and youth mortality, could prove to be a hindrance for any future efforts to reduce the rural–urban gap in mortality.

Substantial improvements in material living conditions are needed to ensure further reductions in mortality rates in rural areas, as they have remained disadvantaged over the past four decades in terms of socioeconomic conditions, economic and educational opportunities, provision of health services, access to essential goods and services, and transportation.^{16,17,19,26} Health policy interventions such as smoking reduction, anti-obesity measures, and improved healthcare access have the potential to reduce health inequalities between rural and urban areas.^{6,19} However, reducing inequalities in education, poverty, unemployment, housing, transportation, and labor market opportunities, the underlying social determinants of health inequalities, is essential from a policy standpoint for tackling long-term health and behavioral inequalities between rural and urban areas.^{5,6,19,46}

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