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INTRODUCTION

Though U.S. life expectancy has increased over the past 50 years, this benefit has not been geographically uniform and certain rural persons and communities face a mortality gap.[1,2] Rural residents experience a shorter life expectancy than urban residents,[3] with higher mortality rates from specific causes such as chronic obstructive pulmonary diseases,[4] coronary heart disease,[5] and lung cancer.[6] Overall, there are higher mortality rates among rural residents for all five leading causes of death – heart disease, stroke, cancer, unintentional injury, and chronic lower respiratory disease – as compared to urban residents.[7] In addition, residents of poor rural areas had a mortality rate in 2005-2009 that was 42% higher than their affluent urban counterparts, and this disparity has increased over time.[8]

Prior studies suggest that individual and family socioeconomic characteristics are partially responsible for elevated rural mortality.[9] For example, rural residents have lower incomes, lower educational attainment, and higher rates of being uninsured compared with urban residents;[10] these characteristics have also been associated with higher mortality rates. A 2011 analysis of deaths in the U.S. in 2000 estimated that poverty and low education increased the risk of death by 75% and 80%, respectively, among adults aged 25-64.[11] The rural-urban mortality difference is even larger for certain demographic groups. Poor blacks living in rural areas had two to three times the mortality risk as more affluent blacks and whites living in urban areas.[8]

Lack of access to health care may also explain the rural-urban mortality gap. Compared to urban places, rural communities have lower availability of primary care, particularly of specialty care, posing challenges to obtaining needed services for some rural residents. For example, rural residents are diagnosed with cancer at later stages of disease than those living in urban areas, which may be due to their more limited access to preventive care services.[12] Diagnosis of cancer at a later stage would account for why residents of rural areas have lower cancer incidence rates but higher death rates than residents of urban areas.[13] In addition, rural trauma deaths often occur outside the hospital setting, in contrast to urban areas.[14] Further, among adults admitted to hospitals for a heart attack, rural residence is associated with higher rates of death, which may be due to differences in patient risk characteristics, such as higher comorbidity among rural residents, or to health care delivery challenges in rural areas.[15,16]

This study aims to address gaps in our understanding of the rural-urban mortality disparity by conducting a time-to-event cohort analysis using a national dataset with detailed information on individual characteristics. Most studies to date have not included multivariable analyses of rural-urban mortality risk differences after controlling for various sociodemographic characteristics that may differ between rural and urban residents. Also, while multiple studies have found that rural-urban gaps in mortality have

Key Findings

- Using pooled data (1997-2011) from adult respondents of a nationally representative survey in the U.S., we found the unadjusted hazard of death (risk of death at any point in time) was 10 percent higher for rural as compared with urban residents.
- When rural-urban differences in respondent age, sociodemographic, and economic factors were accounted for, the hazard of death was not significantly different between the two groups.
- Findings differed somewhat by birth cohort. In particular, for the youngest birth cohort examined (birth years 1965-1986), the rural-urban difference in hazard of death was higher than for older birth cohorts, and remained significantly higher after controlling for respondent characteristics.
- In the youngest birth cohort, accidents/unintentional injuries accounted for approximately one third of deaths among rural adults and one quarter of deaths among urban residents.
- Further analysis is needed to better understand what investments are critical to ensuring that life in a rural place does not correspond to greater risk of death.

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increased over time,[17] it is unclear whether this disparity is experienced equally across birth cohorts, or whether certain generations experience particularly elevated rural death rates. The findings from our study may help to identify potential policy and practice interventions that may reduce the rural-urban mortality gap and lead to longer, healthier lives for rural populations.

METHODS

Data

This study used data from the 1997-2009 National Health Interview Survey (NHIS) linked to deaths through December 2011, which reflected the most recent data available at the time we requested the data files (September, 2017). The NHIS, conducted by the National Center for Health Statistics, Centers for Disease Control and Prevention, is a cross-sectional household survey designed to monitor the health of the U.S. civilian, noninstitutionalized population on a broad range of health topics including trends in illness and disability, health status, and health related behaviors. In-person interviews are conducted in the respondent's home, and self-reported sociodemographic and economic information are also collected. The National Center for Health Statistics conducts mortality follow-up for NHIS respondents by matching respondent information to the U.S.National Death Index using a 14-point identification system.[18] We accessed the linked mortality NHIS data using a harmonized dataset compiled across multiple years of data.[19]

To assess rural-urban residence for NHIS respondents, we linked county of residence to county-level information provided in the Area Health Resources File (AHRF). The AHRF is a national source of county-level health data collected by the federal Health Resources and Services Administration that contains geographic identifiers, including the 2003 Rural-Urban Continuum Codes (RUCC). Developed by the U.S. Department of Agriculture, the RUCC classifies all U.S. counties into nine categories of increasing rurality according to population size and proximity to metropolitan areas.[20] RUCC codes 1-3 were classified as urban counties and codes 4-9 as rural counties. Although a 2013 version of RUCC codes are also available from the AHRF data, we used the 2003 version of the RUCC codes to better align with the NHIS survey year data.

As county of residence is a restricted use variable in the NHIS, we conducted this linkage using remote access to a secured lab in the NCHS Research Data Center. The study protocol was approved by the University of Southern Maine's Institutional Review Board and we adhered to the data suppression criterion included in our data use agreement with NCHS.

Variables

Mortality: Using death certificate data through December 31, 2011, we flagged respondents as decedents if they had a death record linked to their NHIS survey data, or as survivors otherwise. Respondents without a death record by the end of 2011 then were classified as right censored in our study, a concept in time-to-event analysis indicating that the study ended before an event—in this case, death—occurred. Follow-up time was defined as either age at death (for decedents) or age as of December 31, 2011 (for survivors).[21] Given data restrictions for protecting respondents' confidentiality, we did not have date of birth for respondents. Therefore, we subtracted age at time of interview from year at time of interview to approximate birth year.

Respondent characteristics: In addition to rural-urban residence, we included several other respondent characteristics in our analysis, which were assessed at the time of the interview. They were age, sex, race/ethnicity, educational attainment, residential region of the U.S. (Northeast, Midwest, South, West), marital status, poverty status (above or below the federal poverty threshold), and current cigarette status (never smoked, former smoker, or current smoker).

Respondent birth cohort: We additionally included respondent birth cohort as a characteristic in our analysis. National mortality data show rural-urban mortalities increased starting in the mid-1980s, suggesting a cohort effect.[17] We categorized approximate birth year into three birth cohorts that roughly corresponded with the Silent Generation (1912-1945), the Baby Boomers (1946-1964), and Generation X (1965-1986).[22]

Analysis

Our analytic cohort included respondents aged 18 or older, as these individuals were eligible for the adult version of the interview. Our descriptive analyses included estimating the distribution of respondent characteristics by rural-urban status, overall and by birth cohort, with general Chi-square tests to assess whether differences were statistically significant.

We conducted a time-to-event analysis because follow-up time was inconsistent across respondents and the outcome of mortality was only observed for some participants, with the rest being right censored (as described above). In these cases, methods such as logistic regression are inappropriate because they do not account for the fact that the risk of death at a point in time is affected by having survived to that point and follow-up time is variable. We first plotted Kaplan-Meier curves of the cumulative incidence of all-cause mortality for rural and urban respondents, separately. We then used Cox proportional hazard models to estimate the hazard ratios (HR) and 95% confidence intervals (CI)

for all-cause mortality by rural-urban status, overall and by birth cohort. We ran unadjusted models, and adjusted models after including the following covariates: sex, race/ethnicity, region, educational attainment, marital status, poverty status, smoking status, and age at time of interview. As poverty status was missing for approximately 20% of respondents, we reran our unadjusted models on the analytic subpopulation that was included in the adjusted models to estimate the effect of excluding respondents with missing poverty status information.

Among the deaths, we then examined the distribution of the underlying leading causes of death by rural-urban residence, overall and by birth cohort. This 10-level variable is calculated using the underlying cause of death recorded on the death certificate and is the only cause of death variable available in the restricted-use linked mortality files. This variable includes nine mutually-exclusive category-levels (heart disease, cancer, chronic lower respiratory disease, accidents [unintentional injuries], cerebrovascular diseases [stroke], Alzheimer's disease, influenza and pneumonia, kidney disease), with the remaining deaths categorized as single category-level (all other causes). Although suicide is the currently the tenth leading cause of death in the US, these deaths were grouped under "all other causes" because of privacy concerns and very small numbers. We used general Chi-square tests to assess if differences in the distribution of category-levels were statistically significant.

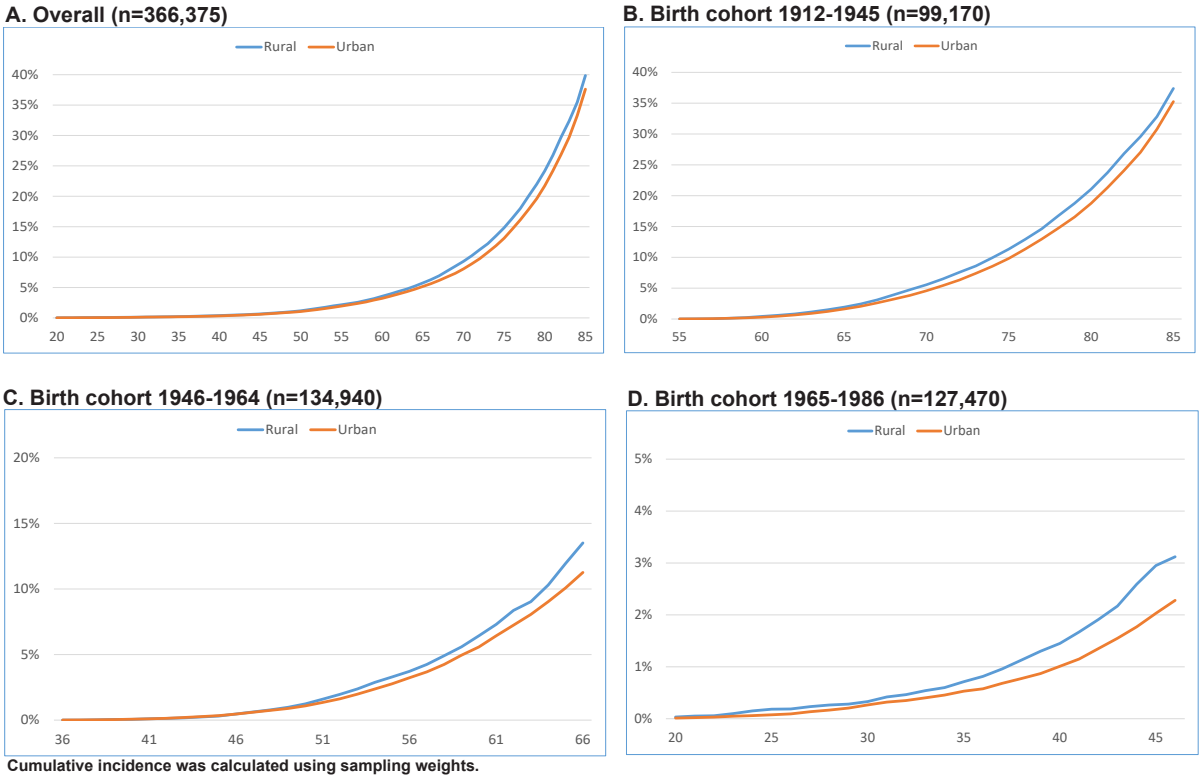
In accordance with NHIS analytic guidelines, we adjusted the sampling weights to account for pooling across survey years 1997-2011. In doing so, our analytic cohort represents the mid-point of the survey years, i.e. approximately 2004. We used these adjusted sampling weights and accounted for the complex survey design of NHIS using SAS and SAS-callable SUDAAN survey procedures.

FINDINGS

Approximately 18.8% (standard error [0.42]; n=67,032) of 366,375 adult respondents to NHIS during 1997-2009 were living in a rural county at the time of the interview. Overall, rural respondents differed from urban respondents for most characteristics examined (Appendix). Rural respondents were older, less likely to be a college graduate, and more likely to be non-Hispanic white, live in the South or Midwest region, be a current smoker, and be living in a household with income below the federal poverty threshold. These differences were also observed within each of the birth cohorts. Rural-respondents were also more likely to have been interviewed for NHIS during the earliest survey years included in our analysis (1997-2000).

The cumulative incidence of all-cause mortality was slightly higher for rural respondents as compared to urban respondents (Figure 1). Overall, 39.9% of rural vs. 37.6% of urban respondents were estimated to have

Figure 1. Weighted Kaplan-Meier curves showing cumulative incidence of all-cause mortality by rural-urban residence, with age as the scale.



Cumulative incidence was calculated using sampling weights.

died by the maximum age at follow-up (85 years of age), which was similar to findings among the oldest birth cohort (1912-1945: 37.4% vs. 35.3% by age 85). Larger relative differences in mortality by maximum age at follow-up were observed for the younger birth cohorts: (1946-1964: 13.5% vs. 11.3% by age 66; and 1965-1986: 3.2% vs. 2.3% by age 45).

The risk of all-cause mortality was greater for rural as compared with urban respondents (Table 1). Overall, rural respondents had 10% higher risk of all-cause mortality compared with their urban counterparts (HR=1.10 [95% CI: 1.06, 1.14]). For the oldest birth cohort (1912-1945), rural respondents also had 10% higher risk of death (HR=1.06, 1.14]); however, for the middle birth cohort (1946-1964), rural respondents had 16% higher risk of death (HR=1.16 [1.08, 1.26]), and for the youngest birth cohort (1965-1986), rural respondents had 42% higher risk of death (HR=1.42 [1.23, 1.64]). After adjustment for respondent characteristics that differed by rural-urban status and could be associated with risk of mortality, all hazard ratio estimates were attenuated. The only hazard ratio that remained statistically significant was for the youngest birth cohort (1946-1964), where rural respondents had 19% higher risk of death as compared to their rural counterparts (HR=1.19 [1.00, 1.42]). Across all models, adjustment for educational attainment alone attenuated the hazard ratio substantially (relative decrease between 4% and 12%), suggesting that this factor by itself accounted for much of the original disparity in rural-urban mortality risk. Hazard ratios estimated from unadjusted models run on the analytic subpopulation included in the adjusted models resulted in nearly the same hazard ratio estimates (data not shown), indicating that restricting the analysis to respondents without missing poverty status did not affect our findings.

Table 1. Hazard ratio estimates for all-cause mortality for rural respondents as compared to urban respondents, overall and by birth cohort, National Health Interview Survey, 1997-2010

Analytic population	Model	Total N	All-cause mortality	All-cause mortality	HR (95% CI)
			N	% (SE)	
All respondents	Unadjusted	366,375	38,561	8.4 (0.07)	1.10 (1.06, 1.14)
	Adjusted	295, 997	28,428	7.5 (0.07)	1.02 (0.98, 1.06)
Birth cohort 1912-1945	Unadjusted	99,170	30,912	28.1 (0.19)	1.10 (1.06, 1.14)
	Adjusted	72,195	22,155	27.4 (0.22)	1.01 (0.98, 1.05)
Birth cohort 1946-1964	Unadjusted	134,940	6,342	4.1 (0.07)	1.16 (1.08, 1.26)
	Adjusted	111,692	5,190	4.0 (0.07)	1.02 (0.94, 1.10)
Birth cohort 1965-1986	Unadjusted	127,470	1,289	0.92 (0.03)	1.42 (1.23, 1.64)
	Adjusted	107,922	1,067	0.89 (0.03)	1.19 (1.00, 1.42)

Adjusted models included age at time of interview, sex, race/ethnicity, region, educational attainment, marital status, poverty status, and smoking status.
Percentages and standard errors were calculated using sampling weights and survey design variables.

Table 2. Number and cause of deaths for rural respondents as compared to urban respondents, overall and by birth cohort, National Health Interview Survey, 1997-2010

	OVERALL			BIRTH COHORT 1912-1944			BIRTH COHORT 1945-1964			BIRTH COHORT 1965-1986		
	Rural	Urban	P-VALUE	Rural	Urban	P-VALUE	Rural	Urban	P-VALUE	Rural	Urban	P-VALUE
Number of deaths	**8,925**	**29,636**		**7,329**	**23,583**		**1,341**	**5,001**		**253**	**1,036**	
Cause of Death	%	%	0.08	%	%	0.01	%	%	0.92	%	%	0.37
Heart disease	18.7	19.5		19.6	21.2		17.4	15.7		7.8	5.2	
Cancer	25.0	25.0		24.1	23.7		32.1	31.9		12.7	17.4	
Chronic lower respiratory diseases	6.7	5.7		7.6	6.5		3.9	3.5		***	1.1	
Accidents (unintentional injuries)	4.5	4.0		2.5	2.1		6.3	6.9		34.2	25.5	
Stroke (cerebrovascular diseases)	5.3	5.6		6.1	6.5		2.9	3.0		1.4	2.0	
Alzheimer's disease	2.3	2.4		2.9	3.1		***	0.1		0.0	***	
Diabetes	2.9	3.2		2.9	3.2		3.7	3.6		***	2.1	
Influenza and pneumonia	2.3	2.0		2.6	2.2		1.0	1.3		2.1	1.6	
Kidney disease	2.3	2.1		2.5	2.1		1.5	1.8		1.7	1.5	
All other causes of death	30.1	30.7		29.4	29.6		31.3	32.2		37.8	43.5	

***Indicates suppressed data cell.
Percentages and standard errors were calculated using sampling weights and survey design variables.
Columns percentages do not always add up to 100.0% due to rounding.

When we examined the distribution of underlying cause of death overall and by birth cohort, we observed several differences between rural and urban respondent deaths (Table 2). Among all birth cohorts, the proportion of deaths caused by chronic lower respiratory diseases, accidents (unintentional injuries), influenza and pneumonia, and kidney disease were higher among rural respondents as compared with urban respondents; however, the general Chi-square test p-value was not significant (p=.08). Similar findings were observed for the oldest birth cohort, with cancer deaths also slightly greater in the rural respondents (Chi-square p<.01). We did not observe statistically significant differences in the distribution of underlying cause of death for the middle and youngest birth cohorts by rural-urban status (both p >.37). However, for both cohorts heart disease deaths were more prevalent among rural respondent deaths (1945-1964 birth cohort: 17.4% vs. 15.7%; 1965-1986 birth cohort: 7.8% vs. 5.2%) and accident deaths were more common among rural respondent deaths in the youngest birth cohort (34.2% vs. 25.5%).

LIMITATIONS

The NHIS is a cross-sectional survey, which limits our ability to assess the temporal sequence of events or establish the causal effect of rural residence on risk of mortality. For example, it is unclear whether rural adults have greater risk of mortality than urban adults because they have health care needs that are not being met in rural communities or whether aspects of rural living influence life span, apart from health care needs. Further, mediating factors, such as history of chronic illness and obesity, may account for the relationship between rural-urban residence and risk of mortality; we did not include these as covariates in our model because we hypothesized they would be too proximate to mortality for many causes of death. Finally, it is possible that respondent characteristics collected at the time of the survey could have changed over the follow-up time, and these changes would not be reflected in our results (e.g., a person could have lived in poverty when surveyed but experienced substantial income growth by the time of their death or censoring, or vice versa). Except for residence information and death, all other measures included in our analysis were self-reported and may have contained inaccuracies; further, deaths included in our analysis only included deaths occurring within the United States.

NHIS survey respondents have been shown to have slightly lower mortality rates than the general population, even when using survey weights, which take non-response bias into account.[23] The NHIS is based on a household sampling frame and therefore excludes persons who are often characterized by poor health, such as those who are incarcerated or otherwise institutionalized and the homeless. However, we have no reason to believe that these overall lower mortality rates are subject to a rural-urban difference.[24]

We used pooled respondent data from 1997-2011 linked to death certificate data through December 31, 2011, which introduces a further issue in regard to generalizability to the U.S. population. Respondents interviewed during earlier survey years had greater follow-up time compared to respondents interviewed in later survey years. As all respondents were alive at the time of interview, this study design artificially deflates the risk of mortality (and increases the survival rates) because it includes older adults, whose birth cohort may have already experienced substantial mortality; this is especially an issue for older adults interviewed closer to the date of censoring. Therefore, the risks of mortality by age 85 shown in our Kaplan Meier curves are not generalizable to persons born during 1912-1986, nor are they generalizable to persons interviewed during any particular NHIS survey year. However, the hazard ratios for urban-rural mortality should not be affected by using pooled respondent data, particularly because our Cox proportional hazard models adjusted for age at the time of interview. In addition, given data suppression restrictions for using the restricted data file, we were unable to calculate standard errors for the survey-weighted Kaplan-Meier curves displayed in Figure 1, or to conduct a log-rank test for differences in survival curves.

A final limitation is that the study includes deaths only through 2011, the most recent year of death data linked to the NHIS at the time we requested the restricted data. Given accelerating rates of rural drug poisonings and suicides, this means that using more recent years of data may yield somewhat different findings and warrants future study.

DISCUSSION

Multiple prior studies have documented a shorter life expectancy and higher mortality rates overall and from specific conditions for rural residents when compared when urban residents, a disparity that has grown over time.[1,4-9] Our overall analyses from 1997-2011 found an unadjusted hazard of death that was 10% higher for rural residents over this time period. However, in a multivariable model controlling for a range of sociodemographic and economic factors, we did not observe a statistically significant difference in mortality. This suggests that over the full time period, across all cohorts, the rural mortality gap was attenuated by sociodemographic risk factors, such as lower levels of educational attainment, family income below the federal poverty level, being unmarried, and smoking history. These findings are consistent with prior research that has shown a higher risk of mortality among non-married adults,[25] low income groups,[26] and persons with low

educational attainment.[27,28] Smoking has been estimated to account for 21% of deaths among men and 17% of deaths among women, and may be responsible for as much as 60% of the mortality disadvantage of southern states compared to states from other regions.[29] The overall rural mortality disparity may result from the fact that sociodemographic and economic risk factors for mortality tend to cluster in rural communities.

Notably, we found distinctly different results for the birth cohort that roughly represents Generation X. The unadjusted risk of all-cause mortality for this cohort was 42% higher among rural versus urban residents and, while this diminished in our multivariable model, the rural disparity persisted even after controlling for sociodemographic risk factors. While this higher risk may reflect residual confounding between rural and urban populations, it's also possible that factors resulting from rural residence could account for the difference. For example, the percentage of deaths due accidents/unintentional injuries were higher among this cohort (with follow-up through age 45) compared to the older cohorts (with follow-up through age 66 or 85), and this cause of death was higher for rural as compared with urban residents. This may be due to a combination of higher rates and different types of accidents in rural places as well as differences in health care system capacity. We know, for example, that rural residents experience higher rates of hospitalization for unintentional injury overall, and for specific types of injury such as motor vehicle accidents, falls, firearms, and poisoning.[30] At the same time, median response times for arrival of emergency medical services are twice as long as for rural residents as for their urban or suburban counterparts.[31] Further research is needed to better understand what accounts for rural-urban differences in mortality risk among this age cohort to determine how best to address the rural penalty that we observed in this study.

As noted in our limitations section, this study is based on deaths that occurred between 1997 and 2011. In more recent years, rates and causes of death rural and urban have been shifting, which means that a more contemporary study will be needed in the future. For example, rates of death from unintended injury have been increasing in both rural and urban areas, but rural rates remain higher and have been increasing at a faster rate for some types of injury, such as falls.[32] Similarly, until 2007, rates of death by drug overdose were higher among urban residents; since then, however, rural rates of death from overdose exceeded those of urban places until 2016,[33] though further analysis of trends using more detailed rural-urban residence level are required. Given some of these changes, the rural-urban differences observed for Generation X adults may be shifting and, as Millennials mature, their experiences may also be different and warrant further exploration.

Our findings generally suggest that the overall mortality penalty in rural areas between 1997 and 2011 may have been driven by social determinants of health, a set of challenges that can be perceived as especially intractable in rural settings. In particular, we found a strong attenuation of the results (to the point that differences were small and not statistically significant) from adding educational attainment alone into our models. This implies that access to educational and other community-based economic development activities may be critical for reducing risk of mortality, but further exploration of this connection is needed. At the same time, among the youngest cohort, the mortality penalty persisted despite control of sociodemographic and economic factors, and while causes of death were predictably different from the older cohorts, causes of death were surprisingly different by rural-urban residence. The differences between rural and urban deaths due to accidents (unintentional injuries) among Generation X may indicate a need for improvement in the rural health infrastructure, such as access to emergency medical services, trauma care, or overdose reversal medications. As these factors were outside the scope of this study, further analysis is needed to better understand what investments are critical to ensuring that life in a rural place does not correspond to greater risk of death.

REFERENCES

1. Murray CJL, Kulkarni SC, Michaud C, et al. Eight Americas: investigating mortality disparities across races, counties, and race-counties in the United States. PLoS Med. 2006;3(9):1513-1524.
2. National Healthcare Quality and Disparities Report chartbook on rural health care. In: Quality AfHRa, ed. Rockville, MD: AHRQ Pub. No. 17(18)-0001-2-EF. ; 2017.
3. National Advisory Committee on Rural Health and Human Services. Mortality and life expectancy in rural America: connecting the health and human service safety nets to improve health outcomes over the life course. . . In. Available at: https://www.hrsa.gov/advisorycommittees/rural/publications/mortality.pdf. Accessed August 15, 20192015.
4. Bethesda, MD: Rural Health Reform Policy Research Center;2014.
5. Kulshreshtha A, Goyal A, Dabhadkar K, Veledar E, Vaccarino V. Urban-rural differences in coronary heart disease mortality in the United States: 1999-2009. Public Health Rep. 2014;129(1):19-29.
6. Atkins GT, Kim T, Munson J. Residence in Rural Areas of the United States and Lung Cancer Mortality. Disease Incidence, Treatment Disparities, and Stage-Specific Survival. Ann Am Thorac Soc. 2017;14(3):403-411.
7. Moy E, Garcia MC, Bastian B, et al. Leading Causes of Death in Nonmetropolitan and Metropolitan Areas--United States, 1999-2014. MMWR-Surveillance Summaries. 2017;66(1):1-8.

8. Singh GK, Siahpush M. Widening rural-urban disparities in all-cause mortality and mortality from major causes of death in the USA, 1969-2009. J Urban Health. 2013;91(2):272-292.
9. Singh GK, Siahpush M. Widening Rural–Urban Disparities in Life Expectancy, U.S., 1969–2009. Am J Prev Med. 2014;46(2):e19-e29.
10. Singh GK, Azuine RE, Siahpush M, Kogan MD. All-cause and cause-specific mortality among US youth: socioeconomic and rural-urban disparities and international patterns. J Urban Health. 2013;90(3):388-405.
11. Galea S, Tracy M, Hoggatt KJ, Dimaggio C, Karpati A. Estimated deaths attributable to social factors in the United States. Am J Public Health. 2011;101(8):1456-1465.
12. Higginbotham JC, Moulder J, Currier M. Rural v. urban aspects of cancer: first-year data from the Mississippi Central Cancer Registry. Fam Community Health. 2001;24(2):1-9.
13. Henley SJ, Anderson RN, Thomas CC, Massetti GM, Peaker B, Richardson LC. Invasive Cancer Incidence, 2004-2013, and Deaths, 2006-2015, in Nonmetropolitan and Metropolitan Counties - United States. MMWR Surveillance Summaries. 2017;66(14).
14. Newgard CD, Fu R, Bulger E, et al. Evaluation of Rural vs Urban Trauma Patients Served by 9-1-1 Emergency Medical Services. JAMA Surg. 2017;152(1):11-18.
15. Agency for Healthcare Research and Quality. 2010 National Healthcare Disparities Report. Rockville, MD: U.S. Department of Health and Human Services, AHRQ.
16. Harris DE, Aboueissa AM, Hartley D. Myocardial infarction and heart failure hospitalization rates in Maine, USA - variability along the urban-rural continuum. Rural and remote health. 2008;8(2):980.
17. Cosby AG, McDoom-Echebiri MM, James W, Khandekar H, Brown W, Hanna HL. Growth and Persistence of Place-Based Mortality in the United States: The Rural Mortality Penalty. Am J Public Health. 2019;109(1):155-162.
18. National Center for Health Statistics, Office of Analysis and Epidemiology. The National Health Interview Survey (1986-2004) Linked Mortality Files, Mortality Follow-up Through 2006: Matching Methodology. Hyattsville, MD: National Center for Health Statistics;2009.
19. Blewett LA, Rivera Drew JA, Griffin R, King ML, Williams KCW. IPUMS Health Surveys: National Health Interview Survey, Version 6.3 [dataset]. Minneapolis, MN: IPUMS;2018.
20. Economic Research Service, U.S. Department of Agriculture. Measuring Rurality: Rural-Urban Continuum Codes. U.S. Department of Agriculture. https://wayback.archive-it.org/5923/20110913215735/http://www.ers.usda.gov/Briefing/Rurality/RuralUrbCon/. Published 2004. Accessed 7 September 2017.
21. Korn EL, Graubard BI, Midthune D. Time-to-event analysis of longitudinal follow-up of a survey: choice of the time-scale. Am J Epidemiol. 1997;145(1):72-80.
22. Colby S. Talkin' 'Bout Our Generations: Will Millennials Have a Similar Impact on America's Institutions as the Baby Boomers? In: United States Census Bureau, ed. Census Blogs. Vol 2019. Washington, DC: United States Census Bureau; 2015.
23. Brown DC, Lariscy JT, Kalousova L. Comparability of Mortality Estimates from Social Surveys and Vital Statistics Data in the United States. Population research and policy review. 2019;38(3):371-401.
24. Keyes KM, Rutherford C, Popham F, Martins SS, Gray L. How Healthy Are Survey Respondents Compared with the General Population?: Using Survey-linked Death Records to Compare Mortality Outcomes. Epidemiology. 2018;29(2):299-307.
25. Johnson NJ, Backlund E, Sorlie PD, Loveless CA. Marital status and mortality: the national longitudinal mortality study. Ann Epidemiol. 2000;10(4):224-238.
26. Chetty R, Stepner M, Abraham S, et al. The Association Between Income and Life Expectancy in the United States, 2001-2014. JAMA. 2016;315(16):1750-1766.
27. Masters RK, Hummer RA, Powers DA. Educational Differences in U.S. Adult Mortality: A Cohort Perspective. Am Sociol Rev. 2012;77(4):548-572.
28. Krueger PM, Tran MK, Hummer RA, Chang VW. Mortality Attributable to Low Levels of Education in the United States. PLoS One. 2015;10(7):e0131809.
29. Fenelon A, Preston SH. Estimating smoking-attributable mortality in the United States. Demography. 2012;49(3):797-818.
30. Coben JH, Tiesman HM, Bossarte RM, Furbee PM. Rural-urban differences in injury hospitalizations in the U.S., 2004. American journal of preventive medicine. 2009;36(1):49-55.
31. Mell HK, Mumma SN, Hiestand B, Carr BG, Holland T, Stopyra J. Emergency Medical Services Response Times in Rural, Suburban, and Urban Areas. JAMA surgery. 2017;152(10):983-984.
32. Olaisen R, Rossen L, Warner M, Anderson R. Unintentional injury death rates in rural and urban areas: United States, 1999–2017. In. NCHS Data Brief, no 343. Hyattsville, MD: National Center for Health Statistics; 2019.
33. Hedegaard H, Miniño A, Warner M. Urban–rural differences in drug overdose death rates, by sex, age, and type of drugs involved, 2017. In: NCHS Data Brief n, ed. Hyattsville, MD: National Center for Health Statistics; 2019.

Appendix. Respondent characteristics for rural and urban residents age 18 and over, National Health Interview Survey 1997-2009

	OVERALL			BIRTH COHORT 1912-1945			BIRTH COHORT 1946-1964			BIRTH COHORT 1965-1986		
	Rural	**Urban**	**p-value**	**Rural**	**Urban**	**p-value**	**Rural**	**Urban**	**p-value**	**Rural**	**Urban**	**p-value**
Total N	67,032	299,343		21,938	77,232		24,544	110,396		19,866	107,604	
	% (SE)	% (SE)		% (SE)	% (SE)		% (SE)	% (SE)		% (SE)	% (SE)	
Age at Time of Interview			<0.01			0.02			0.36			
18-44	47.1 (0.46)	52.9 (0.20)		0.0	0.0		33.0 (0.54)	33.5 (0.23)		100.0	100.0	
45-64	33.6 (0.31)	31.5 (0.15)		29.5 (0.51)	29.4 (0.25)		67.1 (0.54)	66.5 (0.23)				
65-74	10.7 (0.19)	8.4 (0.08)		39.0 (0.50)	37.9 (0.22)		0.0	0.0				
75+	8.6 (0.17)	7.2 (0.09)		31.5 (0.40)	32.7 (0.28)		0.0	0.0				
Sex			0.18			0.91			0.51			0.21
Male	47.8 (0.25)	48.2 (0.12)		44.3 (0.40)	44.2 (0.23)		49.1 (0.39)	48.8 (0.19)		49.0 (0.44)	49.6 (0.21)	
Female	52.2 (0.25)	51.8 (0.12)		55.7 (0.40)	55.8 (0.23)		50.9 (0.39)	51.2 (0.19)		51.0 (0.44)	50.4 (0.21)	
Race/Ethnicity			<0.01			<0.01			<0.01			<0.01
non-Hispanic white	84.5 (0.75)	69.2 (0.27)		89.9 (0.70)	79.3 (0.31)		85.5 (0.74)	71.6 (0.29)		79.4 (1.00)	61.4 (0.35)	
non-Hispanic black	7.5 (0.57)	12.3 (0.19)		5.8 (0.52)	9.5 (0.22)		7.2 (0.57)	12.1 (0.21)		9.3 (0.74)	13.8 (0.24)	
Hispanic	5.4 (0.47)	13.4 (0.19)		2.8 (0.43)	7.7 (0.19)		4.5 (0.42)	11.4 (0.19)		8.3 (0.74)	18.5 (0.26)	
Other	2.6 (0.30)	5.2 (0.09)		1.5 (0.27)	3.5 (0.13)		2.8 (0.32)	4.9 (0.10)		3.1 (0.35)	6.3 (0.12)	
Missing	0.01 (0.00)	0.01 (0.00)		***	0.01 (0.00)		0.01 (0.01)	0.0		*** (0.01)	0.01 (0.00)	
Educational Attainment			<0.01			<0.01			<0.01			<0.01
High school	18.9 (0.37)	13.7 (0.13)		30.4 (0.56)	21.6 (0.26)		13.8 (0.41)	10.0 (0.14)		14.9 (0.53)	12.3 (0.18)	
High school, some college	65.7 (0.33)	59.1 (0.19)		56.2 (0.53)	56.5 (0.27)		67.6 (0.50)	58.4 (0.26)		71.0 (0.53)	60.2 (0.27)	
College graduate	14.8 (0.38)	26.5 (0.22)		12.5 (0.38)	20.9 (0.27)		18.1 (0.49)	30.9 (0.28)		13.7 (0.47)	27.0 (0.28)	
Missing	0.6 (0.05)	0.7 (0.02)		0.9 (0.10)	1.0 (0.05)		0.6 (0.06)	0.7 (0.03)		0.4 (0.06)	0.6 (0.03)	
Region			<0.01			<0.01			<0.01			<0.01
Northeast	10.7 (1.03)	20.3 (0.29)		9.8 (0.94)	23.0 (0.41)		11.5 (1.21)	21.1 (0.34)		10.5 (1.01)	18.2 (0.32)	
Midwest	32.3 (1.01)	23.0 (0.38)		33.5 (1.10)	21.8 (0.42)		32.1 (1.05)	23.0 (0.41)		31.2 (1.22)	23.7 (0.48)	
South	44.3 (1.18)	34.8 (0.38)		44.0 (1.30)	34.7 (0.52)		42.7 (1.22)	34.3 (0.42)		46.5 (1.38)	35.3 (0.45)	
West	12.8 (0.77)	21.9 (0.29)		12.6 (0.91)	20.5 (0.45)		13.7 (0.80)	21.6 (0.34)		11.8 (0.90)	22.8 (0.36)	
Smoking Status			<0.01			<0.01			<0.01			<0.01
Never smoked	51.2 (0.37)	56.2 (0.17)		48.0 (0.48)	47.6 (0.23)		47.4 (0.43)	52.1 (0.23)		57.3 (0.58)	64.0 (0.25)	
Former smoker	22.5 (0.27)	22.0 (0.12)		37.2 (0.50)	39.1 (0.23)		22.6 (36)	23.4 (0.18)		11.0 (0.28)	11.6 (0.13)	
Current smoker	25.7 (0.29)	21.1 (0.14)		14.2 (0.29)	12.5 (0.16)		29.5 (0.42)	23.8 (0.20)		31.1 (0.52)	23.8 (0.22)	
Missing	0.6 (0.05)	0.7 (0.02)		0.6 (0.06)	0.8 (0.04)		0.6 (0.07)	0.7 (0.03)		0.6 (0.07)	0.6 (0.03)	
Poverty Status			<0.01			<0.01			<0.01			<0.01
At or above poverty	69.6 (0.56)	72.8 (0.20)		63.9 (0.72)	65.8 (0.29)		74.4 (0.60)	76.8 (0.21)		69.2 (0.72)	73.5 (0.28)	
Below poverty	12.0 (0.32)	8.7 (0.13)		10.1 (0.33)	7.0 (0.15)		9.1 (0.31)	6.4 (0.11)		16.1 (0.60)	11.2 (0.20)	
Missing	18.4 (0.51)	18.5 (0.16)		26.0 (0.70)	27.3 (0.29)		16.5 (0.54)	16.8 (0.20)		14.7 (0.52)	15.3 (0.18)	
Time Period of Survey			<0.01			<0.01			<0.01			<0.01
1997-2000	33.2 (0.77)	27.9 (0.22)		38.5 (0.83)	34.9 (0.32)		33.5 (0.83)	30.2 (0.27)		30.1 (0.88)	23.2 (0.26)	
2001-2005	36.7 (0.97)	38.9 (0.31)		36.0 (0.92)	39.4 (0.37)		36.7 (1.01)	38.9 (0.35)		39.0 (1.17)	40.6 (0.39)	
2006-2009	30.1 (1.24)	33.3 (0.42)		25.5 (1.23)	25.8 (0.48)		29.8 (1.25)	31.0 (0.46)		30.9 (1.40)	36.2 (0.49)	

Data: National Health Interview Survey and Integrated Health Interview Series, 1997-2009. Percentages and standard errors were calculated using sampling weights and survey design variables. Note: *** Values suppressed for small cell sizes.