Published in final edited form as:

Stroke. 2019 December ; 50(12): 3355–3359. doi:10.1161/STROKEAHA.119.026695.

Stagnating National Declines in Stroke Mortality Mask Widespread County-Level Increases, 2010–2016

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Abstract

Background and Purpose——Recent national and state-level trends show a stalling or reversal of previously declining stroke death rates. These national trends may mask local geographic variation and changes in stroke mortality. We assessed county-level trends in stroke mortality among adults aged 35 to 64 and ≥65 years.

Methods——We used data from National Vital Statistics Systems and a Bayesian multivariate space-time conditional autoregressive model to estimate age-standardized annual stroke death rates for 2010 through 2016 among middle-aged adults (35–64 years) and older adults (≥65 years) in US counties. We used log-linear regression models to estimate average annual and total percent change in stroke mortality during the period.

Results——Nationally, the annual percent change in stroke mortality from 2010 to 2016 was −0.7% (95% CI, −4.2% to 3.0%) among middle-aged adults and −3.5% (95% CI, −10.7% to 4.3%) among older adults, resulting in 2016 rates of 15.0 per 100 000 and 259.8 per 100 000, respectively. Increasing county-level stroke mortality was more prevalent among middle-aged adults (56.6% of counties) compared with among older adults (26.1% of counties). About half (48.3%) of middle-aged adults, representing 60.2 million individuals, lived in counties in which stroke mortality increased.

Conclusions——County-level increases in stroke mortality clarify previously reported national and state-level trends, particularly among middle-aged adults. Roughly 3×as many counties experienced increases in stroke death rates for middle-aged adults compared with older adults. This highlights a need to address stroke prevention and treatment for middle-aged adults while continuing efforts to reduce stroke mortality among the more highly burdened older adults. Efforts to reverse these troubling local trends will likely require joint public health and clinical efforts to

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Disclosures
None.

The online-only Data Supplement is available with this article at https://www.ahajournals.org/doi/suppl/10.1161/STROKEAHA.119.026695.

develop innovative and integrated approaches for stroke prevention and care, with a focus on community-level characteristics that support stroke-free living for all.

Keywords

middle-aged; mortality decline; public health; stroke; vital statistics

Despite long-term declines in stroke mortality, stroke still accounts for over 140 000 deaths each year and remains the fifth leading cause of death in the United States.[1] Recently, the declining trend in national stroke death rates has reversed, particularly among adults 35 to 64 years old.[2] From 2013 to 2015, 75% of US states experienced a slowing, stalling or reversal of previously declining stroke death rates among adults ≥35 years. The biggest increases were observed among states in the South Census Region, in which stroke death rates experienced a statistically significant increase of 4.2% per year from 2013 to 2015 (after declining 3.3% per year from 2006–2013).[2]

While national and state-level trends in stroke mortality have been documented for several decades, local trends in smaller geographic areas are less thoroughly characterized. As seen with heart disease mortality,[3,4] describing only national or state-level changes in mortality may mask important changes in trends occurring at the local level. From a surveillance perspective, understanding geographic disparities in local trends are important for better targeting of limited health resources. Therefore, to better understand these local changes, we assessed county-level trends in stroke death rates between 2010 and 2016 for ages 35 to 64 years and ≥65 years.

Methods

Data Source

Data used in this study can be obtained by submitting a research request to the National Association for Public Health Statistics and Information Systems.[5] Because this research used only publicly available county-level data, institutional review board approval was not required. Using data collected within the National Vital Statistics System,[6] we identified the annual number of deaths attributed to stroke (underlying cause of death *International Classification of Diseases*, *Tenth Revision*, codes I60-I69) that occurred among adults aged ≥35 years nationally and in each US county during 2010 to 2016. We used National Center for Health Statistics bridged-race annual county-level population estimates for death rate calculations.[7]

Estimating Death Rates and Percent Change

We used a Bayesian multivariate space-time conditional autoregressive model that has been previously described[8] to estimate annual county-level death rates for stroke. The model, which includes correlations across space, time and demographic groups of interest, iteratively estimates parameters and borrows strength from adjacent groups to estimate rates with improved precision.[9] Each model was fit using a Markov chain Monte Carlo (MCMC) algorithm developed in R programming language. Using these models, we estimated county-level stroke death rates for middle-aged adults (ages 35–64 years) and older adults (ages ≥65 years) for the years 2010 through 2016 as the medians of the posterior distributions. The 2.5th and 97.5th percentile values from the posterior distributions of the MCMC iterations were used to calculate 95% credible intervals (95% CI). All rate estimates were standardized to the age distribution (by 10-year age bands) of the 2010 US population.[10]

For each MCMC iteration, we calculated average annual and total percent change from 2010 to 2016 for each age group with separate log-linear regression models in each county using the age standardized county-specific rates for all 7 years. Percent change was estimated as the median of all MCMC iterations with a 95% CI determined by the 2.5th and 97.5th percentile values of the MCMC iterations.

Summarizing Trends in Stroke Death Rates

To assess spatiotemporal trends for each age group (35–64 years, ≥65 years), we mapped the estimated 2016 stroke death rates and total percent change (2010–2016) for each county.

To summarize trends, we calculated the proportion of each age group specific population living in counties where stroke death rates increased (ie, the estimated percent change was >0) from 2010 to 2016. Additionally, we calculated the proportion of counties that had an increase in stroke death rates.

Data Suppression

County-level rates were considered unreliable if the CI width was larger than the point estimate, or there were less than 100 people in the age group within a county for any single year.[11] If a county had one or more unreliable estimated stroke death rates between 2010 and 2016 for either age group, estimated death rates, and trends for both age groups in that county were suppressed. This suppression criteria resulted in a common set of counties across age groups. Among the 3115 counties in the United States, 98.9% (n=3081) had reliable stroke death rates for both age groups and all study years (2010–2016) and were included in this study (Table I in the online only Data Supplement).

Results

National Stroke Death Rates and Trends

In 2016, the national age-adjusted stroke death rate was 15.0 per 100 000 (95% CI, 14.8–15.2) among middle-aged adults (aged 35–64 years) and 259.8 per 100 000 (95% CI, 258.4–261.3) among older adults (aged ≥65 years; Table). Nationally, from 2010 through 2016, the total percent change in stroke death rates among middle-aged adults was −0.7% (95% CI, −4.2% to 3.0%), and among older adults was −3.5% (95% CI, −10.7% to 4.3%).

County-Level Stroke Death Rates and Trends

In 2016, the median county-level stroke death rate per 100 000 was 15.4 (inter-decile range, 10.0–25.9) for middle-aged adults and 271.4 (inter-decile range, 215.6–347.0) per 100 000 for older adults (Table). The distribution of total percent change in stroke death rates among counties varied substantially between age groups. Among the middle-aged group, median total percent change was an increase of 3.1% (inter-decile range, −10.4% to 18.9%), while for the older age group the median total percent change was a decrease of 9.1% (inter-decile range, −20.5% to 4.9%).

Increasing stroke death rates were more widespread among the middle-aged adult group, with 56.6% (95% CI, 53.3%–59.4%) of counties experiencing an increase in stroke death rates, compared with 26.1% (95% CI, 23.9%–28.1%) of counties among older adults (Table). About half (48.3% [95% CI, 46.6%–51.0%]) of adults aged 35 to 64 years lived in a county in which stroke death rates for their age group increased between 2010 and 2016 compared with 37.7% (95% CI, 35.5%−39.2%) of adults aged ≥65 years. Over one in 4 counties (27.7%) experienced a relative 10% or higher increase in stroke mortality among adults aged 35 to 64 years. In contrast, among adults aged ≥65 years, almost half of counties (45.3%) experienced a 10% or greater decrease in stroke mortality.

The spatial patterns of county-level stroke death rates in 2016 were similar across age groups, with higher rates occurring primarily in the southeast (Figure). However, the spatial patterns of temporal trends (total percent change) in county-level stroke death rates varied by age group. For middle-aged adults, counties with increasing stroke death rates were widespread across the country. For older adults, increasing stroke death rates were located primarily in parts of the southeast, southern Florida, and the border of Colorado and New Mexico (Figure).

Discussion

Our county-level analysis of recent trends in stroke death rates refines our understanding of previously reported national trends and state-level increases.[2,12] The national stagnation in stroke death rates between 2010 and 2016 concealed pervasive county-level increases. Like recent trends in heart disease death rates,[3,13–15] these increases in county-level stroke death rates were more prevalent among working-aged individuals aged 35 to 64 years than in individuals aged ≥65 years. These results highlight the importance of considering, and accounting for, geographic variation in future stroke mortality research. Additionally, within the context of recent national increases in midlife all-cause mortality,[16] these local increases in stroke death rates help to inform both the geographic focus and the strategies required to improve on these troubling trends.

First, the difference in trends across age groups is remarkable. National trends in stroke death rates are driven primarily by death rates among adults aged ≥65 years, since this age group has the majority of prevalent and incident stroke cases.[2] By stratifying by age group, we were able to reveal the local differences in trends by age group. Roughly 3× as many counties experienced increases in stroke death rates from 2010 to 2016 for ages 35 to 64 compared with ages ≥65 years. This finding illustrates a critical need to improve stroke prevention and treatment among working-age individuals while continuing efforts to reduce stroke mortality among more highly burdened older adults. The documented prevalence of inadequately diagnosed[17] and managed risk factors particularly concerns among adults aged 35 to 64 years.[18] Nationally, this age group, of whom about half live in counties with increasing stroke death rates, represents, annually, an estimated 100 million missed opportunities to address key stroke risk factors, including managing uncontrolled hypertension and cholesterol, diabetes mellitus, reducing physically inactivity, and combustible tobacco product use.[18,19]

This county-level analysis also revealed important geographic patterns in recent stroke death rates and how those rates have changed over time. The highest rates continued to be observed in the long-established Stroke Belt[20,21] in the southern United States, but a majority of the largest increases in stroke death rates occurred outside this area. Therefore, since the southern United States also has the highest prevalence of key traditional stroke risk factors,[22] factors influencing temporal trends in stroke death rates may differ from those influencing cross-sectional rates. County-level increases in stroke death rates may instead reflect county-level variation in increases in stroke risk factors,[23] including hypertension, high cholesterol, diabetes mellitus, obesity, and tobacco use. Additionally, geographic disparities in increasing stroke death rates may stem from local differences in access to care.[24,25] The availability and access to quality stroke care varies across the country, and addressing access to care may be especially important for middle-aged adults. Additionally, socio-economic conditions should be considered in subsequent efforts to understand and address the observed increases in stroke death rates.[26,27]

From a global perspective, our county-level results from the United States suggest the importance of sub-national analyses of stroke mortality trends in gaining greater understanding of the epidemiology of stroke. Historically, declines in stroke death rates in many high-income countries mirrored those in the United States.[28] Recently, as many European countries experienced continued declines,[29] stroke death rates in some countries plateaued, especially in younger adults.[30] As this pattern mirrors recent stagnation in the United States, sub-national estimates of trends in stroke death rates could reveal places with local trends that oppose what was observed nationally. Additionally, the developing world experiences most of the global burden of stroke, leading to the concept of a global stroke belt across Eastern Europe, East and Southeast Asia, Central Africa, and Oceania.[31] Although these countries have also experienced declining stroke death rates since the 1990s,[28] their epidemiological transition to a greater burden of chronic disease has resulted in increases in the numbers of stroke deaths.[32] Given this high burden and the younger age distribution of many developing countries, our results from the United States reinforce the need for continued stroke surveillance in younger populations and potential for geographic variation in stroke death rates in these high burden countries.

Improving the prevention and control of risk factors may then be key to interventions coordinated by both the public health and clinical communities. A combination of evidence-based strategies tailored to younger adults (ages 35–64),[19] coordinated systems of stroke care, and macro-level interventions in the economic, political and social environments[24] should be considered to reverse these troubling trends. For example, the US Centers for Disease Control and Prevention and Centers for Medicare and Medicaid Services have established the Million Hearts 2022 initiative,[33] which aims to prevent one million myocardial infarctions, strokes and other acute cardiovascular events during 2017 to 2021 through the implementation of evidence-based strategies to address the leading causes of heart disease and stroke.[19] Adults 35 to 64 years of age comprises one of the primary priority populations in the Million Hearts 2022 initiative. Additionally, Centers for Disease

Control and Prevention's Paul Coverdell National Acute Stroke Program[34] works with healthcare partners to improve the quality of stroke care and to develop coordinated systems of care to reduce stroke-related death and disability.

The primary limitation of this study is the potential misclassification of deaths based on the use of death certificate data. However, the use of death certificates at the aggregate level for surveillance has been validated and is widely accepted.[35] The use of broad *International Classification of Diseases* categories for stroke further reduces the potential for misclassification.[36] Unlike cohort studies, vital statistics data includes all recorded deaths, minimizing concerns about selection bias and the generalizability. Additionally, by applying our Bayesian model to these data, we were able to generate estimates that were more robust and precise than other methods, and also enabling the reporting of estimates for most counties.[9] Finally, these county-level trends may also vary by sex, race/ethnicity, or other demographic groups. Future research will explore disparities in these spatiotemporal trends.

Widespread increases in stroke death rates at the county level, especially among ages 35 to 64, are alarming, especially since up to 80% are preventable.[37] Efforts to reverse these troubling local trends will require joint efforts from public health and clinical communities to develop innovative and integrated approaches for stroke prevention, with an eye to community-level characteristics that support stroke-free living for all.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Sources of Funding

This work was supported by the US Centers for Disease Control and Prevention.

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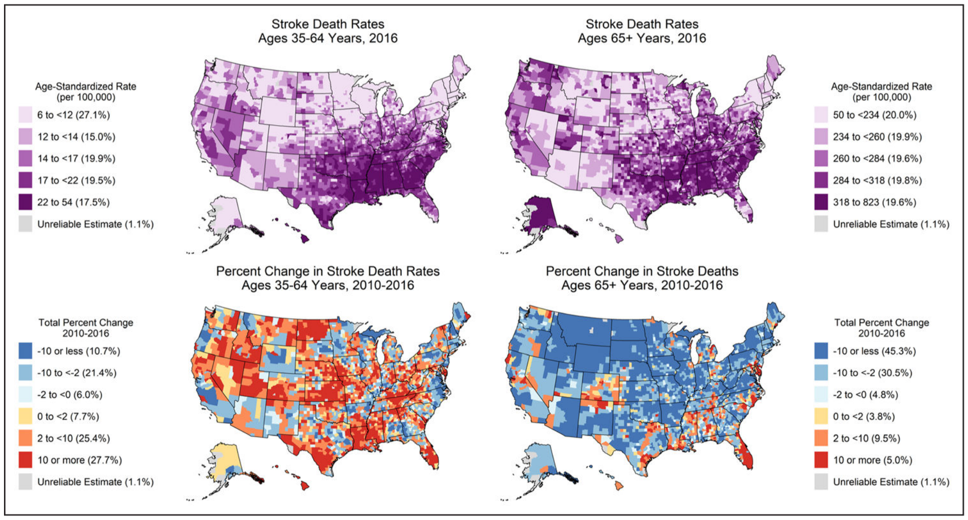

Figure.

County-level estimated stroke death rates in 2016 and total percent change during 2010–2016, by age group, United States, 2010–2016.

Table.

Estimated National and County-Level Stroke Death Rates and Percent Change Among Adults Aged ≥35 Years, by Age Group, United States, 2010–2016

National	**35–64y**	**≥65 y**
2010 rate per 100 000 (95% CI)	15.1 (14.9 to 15.3)	273.1 (271.5 to 274.8)
2016 rate per 100 000 (95% CI)	15.0 (14.8 to 15.2)	259.8 (258.4 to 261.3)
Total relative percent change (95% CI)	−0.7 (−4.2 to 3.0)	−3.5 (−10.7 to 4.3)
County-level (n=3081)		
2010 rate per 100 000 (median, IDR)	14.7 (9.8 to 25.8)	299.3 (239.4 to 380.8)
2016 rate per 100 000 (median, IDR)	15.4 (10.0 to 25.9)	271.4 (215.6 to 347.0)
Total relative percent change (median, IDR)	3.1 (−10.4 to 18.9)	−9.1 (−20.5 to 4.9)
% of counties with increasing rates	56.6 (53.3 to 59.4)	26.1 (24.0 to 28.1)
% of population living in counties with increasing rates	48.3 (46.6 to 51.0)	37.7 (35.5 to 39.2)
Population in counties with increasing rates (in millions)	60.2 (58.1 to 63.6)	18.5 (17.5 to 19.3)

IDR indicates the inter-decile range (10th and 90th percentiles).