Research Article

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Temporal Trends in Stroke Mortality Among U.S. Adults With Hypertension and Diabetes (1999–2023): A Demographic and Geographic Analysis

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Abstract

Objectives: To examine temporal trends in stroke mortality among U.S. adults with comorbid hypertension and diabetes from 1999 to 2023, with specific attention to variations across gender, ethnicity, and geographic region.

Methods: This retrospective study analyzed CDC WONDER mortality data for U.S. adults (≥25 years) with hypertension and diabetes who died from stroke. Age-adjusted mortality rates were stratified by gender, ethnicity, and geographic region. Joinpoint regression identified significant trend changes, with annual percent change (APC) calculated for each segment.

Results: Overall stroke mortality among adults with hypertension and diabetes decreased from 1999-2016 (APC=-1.43%, p<0.01) but increased from 2016-2023 (APC=4.14%, p<0.01). Females showed decline followed by increase (APC=-1.71% from 1999-2017, then 4.84% from 2017-2023), while males showed no significant improvement. Hispanic/Latino populations maintained higher mortality rates than non-Hispanic/Latino groups. The South region displayed persistently high rates, the West exhibited the most pronounced recent increase (APC=4.70% from 2016-2023, p<0.01), and the Northeast maintained the lowest rates with no significant trend.

Conclusions: This study reveals a concerning reversal in stroke mortality trends among adults with hypertension and diabetes, with rates declining until 2016 followed by significant increases through 2023. Substantial demographic and geographic variations highlight persistent disparities requiring targeted interventions. These findings underscore the need for renewed public health efforts to address stroke risk in this vulnerable population.

Keywords: Stroke mortality, Hypertension-diabetes comorbidity, Health disparities, Temporal trends, CDC WONDER

Introduction

Stroke remains a leading cause of mortality and disability worldwide, with particularly heightened risk among individuals with comorbid hypertension and diabetes mellitus.[1,2] These two chronic conditions create a synergistic pathophysiological environment that accelerates cerebrovascular damage through multiple mechanisms, including endothelial dysfunction, increased oxidative stress, and enhanced inflammatory processes.[3] While significant advancements in stroke prevention, acute management, and rehabilitation strategies have emerged over recent decades,

the impact of these developments on mortality trends specifically among this high-risk population has not been comprehensively characterized across demographic and geographic dimensions in the United States.

Previous research has documented overall declines in stroke mortality in the general U.S. population from the late 1990s through the mid-2010s, attributed largely to improved hypertension control, smoking cessation initiatives, and enhanced acute stroke care systems.[4,5] However, concerning evidence has emerged suggesting potential reversals in this favorable trend in recent

years, particularly among younger adults and specific racial/ethnic groups.[6,7] What remains unclear is whether similar trend reversals exist specifically among individuals with both hypertension and diabetes—a population representing approximately 22-25% of U.S. adults with hypertension[8]—and how these patterns may vary across gender, ethnicity, and geographic regions. Such granular analysis is essential for identifying vulnerable subpopulations and informing targeted public health interventions.

The objective of this study was to examine temporal trends in stroke mortality among U.S. adults with comorbid hypertension and diabetes from 1999 through 2023, with specific attention to potential inflection points and variations across gender (male, female), ethnicity (Hispanic/Latino, non-Hispanic/Latino), and geographic region (Northeast, Midwest, South, West). By analyzing these patterns using CDC WONDER database mortality data, this research aims to identify critical periods of change in stroke mortality trajectories and illuminate disparities that may require targeted clinical and public health responses to address this significant burden among a particularly vulnerable population.

Methods

Study Design and Data Source

This retrospective, population-based study utilized mortality data from the Centers for Disease Control and Prevention's Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) database for the period 1999-2023.[9] The CDC WONDER system provides access to publicly available mortality data derived from death certificates filed in all 50 U.S. states and the District of Columbia, which are processed and coded according to International Classification of Diseases, 10th Revision (ICD-10) standards.[10]

Study Population

The study population included U.S. adults (aged ≥25 years) with underlying hypertensive diseases (ICD-10: I10-I15) and diabetes mellitus (ICD-10: E10-E14) who died from stroke-related causes. Stroke mortality was identified using ICD-10 codes for subarachnoid hemorrhage (I60.0-I60.9), intracerebral hemorrhage (I61.0-I61.9), non-traumatic intracranial hemorrhage (I62.0-I62.9), cerebral infarction (I63.0-I63.9), unspecified stroke (I64), and cerebrovascular disease sequelae (I69.0-I69.8). Mortality data were stratified by gender (male and female), ethnicity (Hispanic/Latino and Non-Hispanic/Latino), and geographic region (Northeast, Midwest, South, and West), as defined by the U.S. Census Bureau.

Statistical Analysis

Age-adjusted mortality rates were calculated using the direct method with the 2000 U.S. standard population as the reference population and expressed as deaths per 100,000 population.[11] Ninety-five percent confidence intervals (95% CI) were calculated for all mortality rates.

To identify temporal trends and potential changes in trends, we performed joinpoint regression analysis using the Joinpoint Regression Program, version 4.9.1.0 (National Cancer Institute).[12] This method identifies points (joinpoints) where there is a significant change in the linear slope of the mortality trend. The model selection was based on the permutation test with a significance level of 0.05.

For each identified segment of the trend, we calculated the annual percent change (APC) with corresponding 95% confidence intervals. An APC was considered statistically significant if its 95% confidence interval did not include zero (p<0.05). For trend segments with no significant joinpoints, we calculated the average annual percent change (AAPC) for the entire study period. All analyses were conducted for the overall population and separately for each stratified group (gender, ethnicity, and geographic region).

Ethical Considerations

This study used publicly available, de-identified death certificate data and was therefore exempt from institutional review board (IRB) approval in accordance with the federal exemption criteria outlined in 45 CFR §46.104(d)(4).

Results

From 1999 to 2023, age-adjusted stroke mortality rates among U.S. adults with hypertension and diabetes exhibited distinctive temporal patterns characterized by initial decline followed by recent increase. The overall age-adjusted mortality rate was 0.06 per 100,000 (95% CI: 0.04-0.07) in 1999, increased substantially to 3.07 per 100,000 (95% CI: 2.99-3.16) in 2000, and after fluctuations over two decades, reached 3.24 per 100,000 (95% CI: 3.17-3.31) in 2023 (Figure 1). Joinpoint regression analysis identified two distinct temporal segments in the overall trend: a significant declining trend from 1999 to 2016 with an annual percent change (APC) of -1.43% (95% CI: -2.30, -0.54, p<0.01), followed by a significant increasing trend from 2016 to 2023 with an APC of 4.14% (95% CI: 1.45, 6.91, p<0.01) (Table 1).
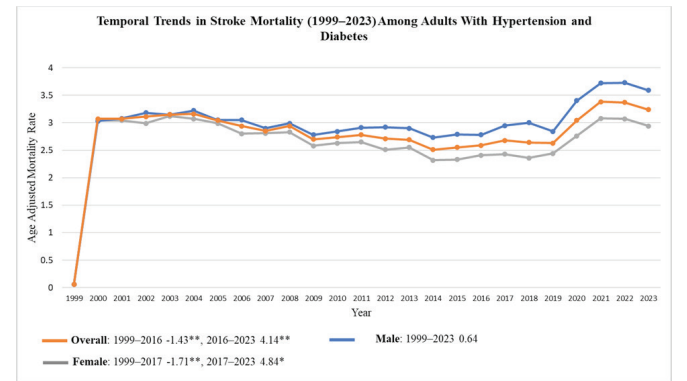

Figure 1. Temporal Trends in Stroke Mortality (1999–2023) Among Adults with Hypertension and Diabetes.

Table 1. Joinpoint Regression Analysis of Temporal Trends in Stroke Mortality Among U.S. Adults with Hypertension and Diabetes, by Demographic and Geographic Subgroups, 1999–2023.

Subgroup	Segment	APC (95% CI)	p-Value
Overall			
Overall - Segment 1	1999–2016	−1.43 (−2.30, −0.54)	<0.01*
Overall - Segment 2	2016–2023	4.14 (1.45, 6.91)	<0.01*
Gender			
Female - Segment 1	1999–2017	−1.71 (−2.70, −0.71)	<0.01*
Female - Segment 2	2017–2023	4.84 (0.21, 9.68)	0.04*
Male	1999–2023	0.64 (−0.14, 1.44)	0.10
Ethnicity			
Hispanic/Latino - Segment 1	2000–2018	−1.06 (−1.66, −0.45)	<0.01*

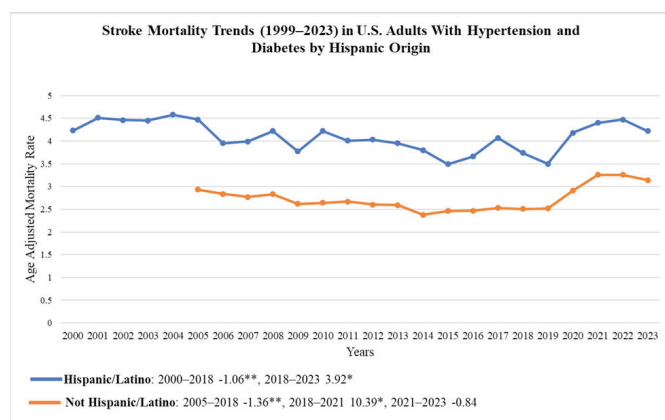|			
Hispanic/Latino - Segment 2	2018–2023	3.92(0.67, 7.27)	0.02*
Not Hispanic/Latino - Segment 1	2005–2018	−1.36 (−1.81, −0.90)	<0.01*
Not Hispanic/Latino - Segment 2	2018–2021	10.39(1.27, 20.33)	0.03*
Not Hispanic/Latino - Segment 3	2021–2023	−0.84 (−8.82, 7.83)	0.83
Region			
Northeast	1999–2023	−0.52 (−1.59, 0.57)	0.33
Midwest - Segment 1	2000–2017	−1.48 (−2.01, −0.95)	<0.01*
Midwest - Segment 2	2017–2023	3.33 (0.82, 5.90)	0.01*
South	1999–2023	0.58 (−0.43, 1.59)	0.25
West - Segment 1	2000–2016	−1.87 (−2.46, −1.28)	<0.01*
West - Segment 2	2016–2023	4.70(2.82, 6.61)	<0.01*

Figure 2. Stroke Mortality Trends (1999–2023) in U.S. Adults with Hypertension and Diabetes by Hispanic Origin.

Stratification by gender revealed notable differences in temporal patterns. Among females, stroke mortality rates followed a trajectory similar to the overall population, with a significant decline from 1999 to 2017 (APC = -1.71%; 95% CI: -2.70, -0.71, p<0.01) followed by a significant increase from 2017 to 2023 (APC = 4.84%; 95% CI: 0.21, 9.68, p=0.04) (Table 1). The mortality rate among females was 0.06 per 100,000 (95% CI: 0.05-0.08) in 1999, peaked at 3.12 per 100,000 (95% CI: 3.02-3.23) in 2003, reached a low of 2.32 per 100,000 (95% CI: 2.24-2.40) in 2014, and then increased to 2.94 per 100,000 (95% CI: 2.85-3.02) by 2023 (Figure 2). In contrast, males exhibited no significant temporal trend over the entire study period (APC = 0.64%; 95% CI: -0.14, 1.44, p=0.10), with rates ranging from 3.03 per 100,000 (95% CI: 2.90-3.16) in 2000 to 3.59 per 100,000 (95% CI: 3.48-3.70) in 2023 (Table 1, Figure 1).

Analysis by ethnicity demonstrated that Hispanic/Latino populations consistently maintained higher stroke mortality rates than non-Hispanic/Latino populations throughout the study period. Hispanic/Latino populations showed a significant declining trend from 2000 to 2018 (APC = -1.06%; 95% CI: -1.66, -0.45, p<0.01) followed by a significant increase from 2018 to 2023 (APC = 3.92%; 95% CI: 0.67, 7.27, p=0.02) (Table 1). Mortality rates among Hispanic/Latino individuals ranged from a high of 4.58 per 100,000 (95% CI: 4.17-4.99) in 2004 to a low of 3.49 per 100,000 (95% CI: 3.22-3.75) in 2015, before increasing to 4.22 per 100,000 (95% CI: 3.97-4.47) in 2023 (Figure 2). The non-Hispanic/Latino population, for which data were available from 2005 onward, demonstrated a more complex pattern with three distinct segments: a significant decline from 2005 to 2018 (APC

= -1.36%; 95% CI: -1.81, -0.90, p<0.01), a sharp significant increase from 2018 to 2021 (APC = 10.39%; 95% CI: 1.27, 20.33, p=0.03), and a non-significant decline from 2021 to 2023 (APC = -0.84%; 95% CI: -8.82, 7.83, p=0.83) (Table 1). Rates for non-Hispanic/Latino individuals ranged from 2.38 per 100,000 (95% CI: 2.31-2.44) in 2014 to 3.26 per 100,000 (95% CI: 3.19-3.34) in 2021 (Figure 2).
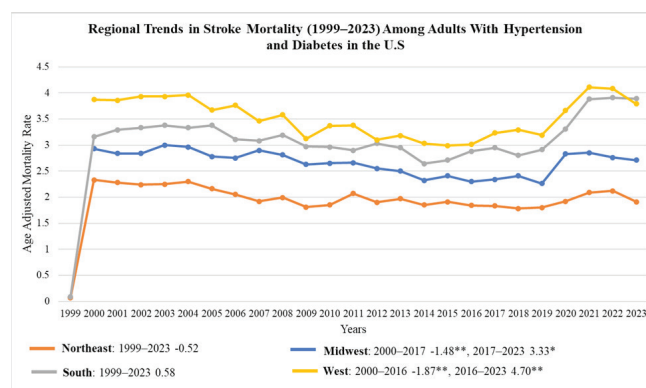

Figure 3. Regional Trends in Stroke Mortality (1999–2023) Among Adults with Hypertension and Diabetes in the U.S

Geographic analysis revealed substantial regional variations in both mortality rates and temporal trends. The Northeast region maintained the lowest mortality rates throughout most of the study period with no significant overall trend (APC = -0.52%; 95% CI: -1.59, 0.57, p=0.33), ranging from 2.33 per 100,000 (95% CI: 2.17-2.48) in 2000 to 1.91 per 100,000 (95% CI: 1.79-2.03) in 2023 (Table 1, Figure 3). The Midwest region demonstrated a significant decline from 2000 to 2017 (APC = -1.48%; 95% CI: -2.01, -0.95, p<0.01) followed by a significant increase from 2017 to 2023 (APC = 3.33%; 95% CI: 0.82, 5.90, p=0.01), with rates ranging from 2.93 per 100,000 (95% CI: 2.77-3.09) in 2000 to 2.71 per 100,000 (95% CI: 2.58-2.85) in 2023 (Table 1, Figure 3). The South region displayed the highest mortality rates in recent years with no significant trend over the entire study period (APC = 0.58%; 95% CI: -0.43, 1.59, p=0.25), increasing from 3.16 per 100,000 (95% CI: 3.02-3.30) in 2000 to 3.89 per 100,000 (95% CI: 3.77-4.01) in 2023(Table 1, Figure 3). The West region exhibited the most pronounced shift in trend, with a significant decline from 2000 to 2016 (APC = -1.87%; 95% CI: -2.46, -1.28, p<0.01) followed by a significant increase from 2016 to 2023 (APC = 4.70%; 95% CI: 2.82, 6.61, p<0.01), with rates ranging from 3.87 per 100,000 (95% CI: 3.66-4.07) in 2000 to a low of 2.99 per 100,000 (95% CI: 2.84-3.14) in 2015, before rising to 3.79 per 100,000 (95% CI: 3.63-3.94) in 2023 (Table 1, Figure 3).

Discussions

This study examined temporal trends in stroke mortality among U.S. adults with comorbid hypertension and diabetes from 1999 to 2023, revealing a concerning pattern: after sustained improvement through 2016 (APC = -1.43%), a significant reversal occurred with increasing mortality rates (APC = 4.14% from 2016-2023). This pattern was observed across multiple demographic and geographic subgroups, suggesting a widespread shift in stroke outcomes among this high-risk population. The initial decline aligns with previous research on general population stroke trends[4,13] and likely reflects advancements in acute stroke care, improved hypertension and diabetes management, expanded use of antithrombotic medications, and broader adoption of evidence-based secondary prevention strategies.[14] However, the reversal of this positive trend warrants serious attention, as our findings indicate a more pronounced increase than the slowing trends previously reported

in the general population,[15] despite continued medical advances.

Our demographic analyses revealed important disparities: females demonstrated a significant decline followed by a sharp increase (APC = -1.71% from 1999-2017, then 4.84% from 2017-2023), while males showed no significant trend throughout the study period, suggesting potential differences in risk factor profiles, healthcare access, or treatment approaches. The Hispanic/Latino population maintained consistently higher mortality rates than non-Hispanic/Latino individuals throughout the study period, with a particularly sharp increase among non-Hispanic/Latino individuals from 2018 to 2021 (APC = 10.39%), possibly reflecting pandemic-related disruptions to healthcare.[16] Geographic analysis identified substantial regional variations, with the Northeast maintaining relatively stable and lower mortality rates, while the South region displayed persistently higher rates aligned with the established "stroke belt" concept,[17] and the West showed the most pronounced recent increase (APC = 4.70% from 2016-2023), representing a departure from its historically favorable outcomes.

Several factors may contribute to these concerning trends, including rising obesity prevalence and associated cardiometabolic conditions,[18] potential plateaus in the quality of hypertension and diabetes management,[19] socioeconomic barriers affecting chronic disease management,[20] and disruptions to both acute stroke care and ongoing management of chronic conditions during the COVID-19 pandemic.[21]

Our study has several strengths, including the use of comprehensive national mortality data spanning a 25-year period, the specific focus on a high-risk population with dual diagnoses of hypertension and diabetes, and the detailed stratification by key demographic and geographic factors. The application of joinpoint regression analysis allowed for precise identification of trend changes beyond what simple linear analyses might detect.

However, several limitations must be acknowledged. First, death certificate data may contain inaccuracies in cause-of-death coding and inconsistencies in reporting of comorbid conditions. Second, our analysis could not account for potential changes in death certificate coding practices over time. Third, the ecological nature of our study precludes examination of individual-level factors that may explain observed trends. Fourth, we lacked data on stroke subtypes, severity, treatment approaches, and risk factor control. Fifth, non-Hispanic/Latino data were only available from 2005 onward, limiting temporal comparisons with other groups.

Our findings have important implications for public health and clinical practice. The reversal of previously favorable trends calls for renewed attention to stroke prevention and management strategies specifically targeted at individuals with comorbid hypertension and diabetes. Enhanced efforts to optimize blood pressure and glycemic control, along with aggressive management of other vascular risk factors, may be needed to restore the previous trajectory of improvement. The significant disparities observed across gender, ethnic, and geographic lines suggest that these efforts should be tailored to address the specific needs of vulnerable subpopulations.

Future research should examine the potential causes of the observed trend reversal, including changes in risk factor prevalence, treatment patterns, healthcare access, and social determinants of health. Studies incorporating individual-level data could help identify specific patient characteristics associated with increased stroke mortality risk. Additionally, the impact of the COVID-19 pandemic on stroke care and outcomes among those with hypertension and diabetes merits detailed investigation.

In conclusion, our study reveals a concerning reversal in stroke mortality trends among U.S. adults with hypertension and diabetes, with rates declining until approximately 2016 followed by significant increases through 2023. This pattern was observed across multiple demographic and geographic subgroups, though with important variations in timing and magnitude. These findings highlight the need for renewed public health and clinical efforts to address stroke risk in this vulnerable population, with particular attention to addressing persistent disparities across gender, ethnic, and geographic dimensions.

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