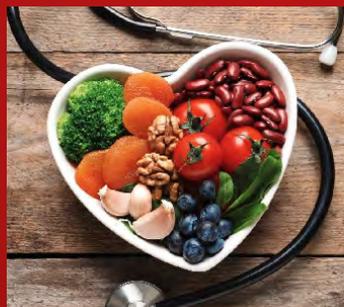


# PREVENTING CHRONIC DISEASE

PUBLIC HEALTH RESEARCH, PRACTICE, AND POLICY



## Global Responses to Prevent, Manage, and Control Cardiovascular Disease



U.S. Department of  
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*Preventing Chronic Disease* (PCD) is a peer-reviewed public health journal sponsored by the Centers for Disease Control and Prevention and authored by experts worldwide. PCD was established in 2004 by the National Center for Chronic Disease Prevention and Health Promotion with a mission to promote dialogue among researchers, practitioners, and policy makers worldwide on the integration and application of research findings and practical experience to improve population health.

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# Table of Contents

01. **Global Responses to Prevent, Manage, and Control Cardiovascular Diseases**  
Coronado F, Melvin SC, Bell RA, Zhao G. Global Responses to Prevent, Manage, and Control Cardiovascular Diseases. *Prev Chronic Dis* 2022;19:220347.
  02. **Effect of Vitamin D on Blood Pressure and Hypertension in the General Population: An Update Meta-Analysis of Cohort Studies and Randomized Controlled Trials**  
Zhang D, Cheng C, Wang Y, Sun H, Yu S, Xue Y, et al. Effect of Vitamin D on Blood Pressure and Hypertension in the General Population: An Update Meta-Analysis of Cohort Studies and Randomized Controlled Trials. *Prev Chronic Dis* 2020;17:190307.
  03. **Self-Measured Blood Pressure Monitoring: Program Planning, Implementation, and Lessons Learned From 5 Federally Qualified Health Centers in Hawaii**  
Creech WL, Towner BC, Battista RA. Physical Activity Among Adults in Rural Western North Carolina During the COVID-19 Pandemic. *Prev Chronic Dis* 2022;19:220112.
  04. **CDC's Sodium Reduction in Communities Program: Evaluating Differential Effects in Food Service Settings, 2013–2016**  
Jordan J, Hickner H, Whitehill J, Yarnoff B. CDC's Sodium Reduction in Communities Program: Evaluating Differential Effects in Food Service Settings, 2013–2016. *Prev Chronic Dis* 2020;17:190446.
  05. **The Arkansas Minority Barber and Beauty Shop Health Initiative: Meeting People Where They Are**  
Smith C, Porter A III, Biddle J, Balamurugan A, Smith MR. The Arkansas Minority Barber and Beauty Shop Health Initiative: Meeting People Where They Are. *Prev Chronic Dis* 2020;17:200277.
  06. **Dose–Response Association Between High-Density Lipoprotein Cholesterol and Stroke: A Systematic Review and Meta-Analysis of Prospective Cohort Studies**  
Qie R, Liu L, Zhang D, Han M, Wang B, Zhao Y, et al. Dose–Response Association Between High-Density Lipoprotein Cholesterol and Stroke: A Systematic Review and Meta-Analysis of Prospective Cohort Studies.
  07. **Racial/Ethnic and Geographic Variations In Long-Term Survival Among Medicare Beneficiaries After Acute Ischemic Stroke**  
Tong X, Schieb L, George MG, Gillespie C, Merritt RK, Yang Q. Racial/Ethnic and Geographic Variations In Long-Term Survival Among Medicare Beneficiaries After Acute Ischemic Stroke. *Prev Chronic Dis* 2021;18:200242.
  08. **Examining Stroke Disparities in Florida: Relationships Among County Classification, Age-Adjusted Stroke Mortality Rates, and the Presence of Primary Stroke Centers**  
Tshiswaka DI, Murphy C, Whembolua G, Williams O. Examining Stroke Disparities in Florida: Relationships Among County Classification, Age-Adjusted Stroke Mortality Rates, and the Presence of Primary Stroke Centers. *Prev Chronic Dis* 2021;18:200561.
-

09. **Reducing Sodium Intake in Community Meals Programs: Evaluation of the Sodium Reduction in Communities Program, Arkansas, 2016–2019**  
Long CR, Spear MJ, Bogulski CA, Rowland B, Langston K, Faitak B, et al. Reducing Sodium Intake in Community Meals Programs: Evaluation of the Sodium Reduction in Communities Program, Arkansas, 2016–2019. *Prev Chronic Dis* 2021;18:210028.
10. **COVID-19 Pandemic and Quality of Care and Outcomes of Acute Stroke Hospitalizations: the Paul Coverdell National Acute Stroke Program**  
Tong X, King SMC, Asaithambi G, Odom E, Yang Q, Yin X, et al. COVID-19 Pandemic and Quality of Care and Outcomes of Acute Stroke Hospitalizations: the Paul Coverdell National Acute Stroke Program. *Prev Chronic Dis* 2021;18:210130.
11. **Differences in Blood Pressure Levels Among Children by Sociodemographic Status**  
Goulding M, Goldberg R, Lemon SC. Differences in Blood Pressure Levels Among Children by Sociodemographic Status. *Prev Chronic Dis* 2021;18:210058.
12. **Infant Mortality and Maternal Risk Factors in Texas: Highlighting Zip Code Variations in 2 At-Risk Counties, 2011–2015**  
Salahuddin M, Matthews KJ, Elerian N, Lakey DL, Patel DA. Infant Mortality and Maternal Risk Factors in Texas: Highlighting Zip Code Variations in 2 At-Risk Counties, 2011–2015. *Prev Chronic Dis* 2022;19:210266.
13. **Cardiovascular Disease Risk Factors in US Adults With Vision Impairment**  
Mendez I, Kim M, Lundeen EA, Loustalot F, Fang J, Saaddine J. Cardiovascular Disease Risk Factors in US Adults With Vision Impairment. *Prev Chronic Dis* 2022;19:220027.
14. **Commitment to Hypertension Control During the COVID-19 Pandemic: Million Hearts Initiative Exemplars**  
Commitment to Hypertension Control During the COVID-19 Pandemic: Million Hearts Initiative Exemplars
15. **Differences in Geographic Patterns of Absolute and Relative Black–White Disparities in Stroke Mortality in the United States**  
Flynn A, Vaughan AS, Casper M. Differences in Geographic Patterns of Absolute and Relative Black–White Disparities in Stroke Mortality in the United States. *Prev Chronic Dis* 2022;19:220081.
16. **Cigarette Smoking Among US Adults With Selected Chronic Diseases Associated With Smoking, 2010–2019**  
Loretan CG, Cornelius ME, Jamal A, Cheng YJ, Homa DM. Cigarette Smoking Among US Adults With Selected Chronic Diseases Associated With Smoking, 2010–2019. *Prev Chronic Dis* 2022;19:220086.
17. **Building Noncommunicable Disease Workforce Capacity Through Field Epidemiology Training Programs: Experience From India, 2018–2021**  
Ramalingam A, Raju M, Ganeshkumar P, Yadav R, Tanwar S, Sakthivel M, et al. Building Noncommunicable Disease Workforce Capacity Through Field Epidemiology Training Programs: Experience From India, 2018–2021. *Prev Chronic Dis* 2022;19:220208.

18. **Disparities in Influenza Vaccination Coverage and Associated Factors Among Adults with Cardiovascular Disease, United States, 2011–2020**  
Parekh T, Javed Z, Khan SU, Xue H, Nasir K. Disparities in Influenza Vaccination Coverage and Associated Factors Among Adults with Cardiovascular Disease, United States, 2011–2020. *Prev Chronic Dis* 2022;19:220154.
19. **A Qualitative Study of Perceptions, Strengths, and Opportunities in Cardiometabolic Risk Management During Pregnancy and Postpartum in a Georgia Safety-Net Hospital, 2021**  
Stanhope KK, Levinson AN, Stallworth CT, Leruth S, Clevenger E, Master M, et al. A Qualitative Study of Perceptions, Strengths, and Opportunities in Cardiometabolic Risk Management During Pregnancy and Postpartum in a Georgia Safety-Net Hospital, 2021. *Prev Chronic Dis* 2022;19:220059.
20. **A Dynamic Visualization Tool of Local Trends in Heart Disease and Stroke Mortality in the United States**  
Le P, Casper M, Vaughan AS. A Dynamic Visualization Tool of Local Trends in Heart Disease and Stroke Mortality in the United States. *Prev Chronic Dis* 2022;19:220076.
21. **Rapid Evaluations of Telehealth Strategies to Address Hypertension: A Mixed-Methods Exploration at Two US Health Systems During the COVID-19 Pandemic**  
Sreedhara M, Suvada K, Bostic M, Scott A, Blum E, Jordan J, et al. Rapid Evaluations of Telehealth Strategies to Address Hypertension: A Mixed-Methods Exploration at Two US Health Systems During the COVID-19 Pandemic. *Prev Chronic Dis* 2022;19:220219.

GUEST EDITORIAL

# Global Responses to Prevent, Manage, and Control Cardiovascular Diseases

Fátima Coronado, MD, MPH<sup>1</sup>; Sandra Carr Melvin, DrPh, MPH, MLS<sup>2</sup>;  
Ronny A. Bell, PhD, MS<sup>3</sup>; Guixiang Zhao, MD, PhD<sup>1</sup>

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PEER REVIEWED

## Introduction

### Cardiovascular disease burden

Cardiovascular disease (CVD), a group of disorders of the heart and blood vessels that includes coronary heart disease, stroke, congestive heart failure, and other conditions, is the leading cause of death worldwide and a major contributor to disability. In 2020, an estimated 523 million people had some form of CVD, and approximately 19 million deaths were attributable to CVD; this represents approximately 32% of all global deaths and is an absolute increase of 18.7% from 2010 (1,2). Global trends for disability-adjusted life years for CVD and the CVD burden attributable to modifiable risk factors have also continued to increase steadily since 1990 (3). In the US, nearly half of adults (approximately 127 million) had 1 or more CVD condition (2). Provisional mortality data for 2021 indicate that even during the COVID-19 pandemic, heart disease and stroke remained the first and the fifth leading causes of death in the US, respectively (4). Despite advancements in the management of CVD and other health outcomes worldwide, minority, disadvantaged, and underserved populations continue to experience significant health disparities, with these disparities exacerbated during the COVID-19 pandemic (5,6). This special collection of *Preventing Chronic Disease* (PCD) highlights public health research, evaluation, and programmatic implementation that incorporate the lens of health equity to address CVD and improve the cardiovascular health of diverse populations.

### Themes of the collection

In recent years, researchers and public health programs and practices have focused on preventing, managing, and controlling traditional CVD risk factors by instituting timely intervention programs, identifying social determinants of health (SDOH), examining disparities in CVD risks, assessing the COVID-19 pandemic's impact on CVD risks, and implementing collective efforts through community-based approaches to achieve population-level improvements in cardiovascular health. This special PCD collection of 20 articles published from January 2020 through November 2022 highlights some of these efforts by using multiple data sources collected before or during the pandemic. For instance, cigarette smoking and risk-enhancing factors related to pregnancy have been shown to increase CVD risks with significant implications (eg, increased infant mortality). Disparities in hypertension, stroke, and stroke mortality exist, exhibiting significant sociodemographic (eg, racial) and geographic (eg, rural–urban, county, zip code) variations. Intervention programs, such as behavioral modifications strengthening chronic disease awareness, use of self-measured blood pressure monitoring, and sodium intake reduction, are evaluated. The impact of COVID-19 on CVD is also explored. Finally, systematic reviews and meta-analyses evaluated the associations of circulating vitamin D levels, vitamin D supplementation, or high-density lipoprotein cholesterol (HDL-C) with blood pressure or stroke. These 20 articles advance our understanding of effective CVD risk management and intervention programs in multiple settings — in the general population and among high-risk groups — with a health equity lens across 3 broad themes further explored in this essay:

1. Examining factors contributing to CVD risk
2. Exploring factors contributing to disparities in CVD
3. Using community-based approaches to decrease CVD



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## Examining the Factors Contributing to CVD Risk

The greatest contributors to CVD-related years of life lost globally are tobacco exposure, hypertension, high body mass index (BMI), and high fasting plasma glucose (3). Tobacco exposure, including cigarette smoking, secondhand smoke, and use of smokeless tobacco, contributed to 8.7 million deaths worldwide in 2019, one-third of which were due to CVD (3). Hypertension affects more than 4 billion people worldwide, representing a near doubling in the absolute prevalence of hypertension since 1990 (3). In the US, nearly half of adults (47%) have hypertension, but only about 1 in 4 (24%) have their condition under control (7). Elevated BMI continues to increase globally, with significant effects on death, disability, and quality of life (3). The prevalence of obesity has increased worldwide in the past 50 years, reaching pandemic levels. Obesity represents a major health challenge because it substantially increases the risk of diseases such as hypertension, myocardial infarction, stroke, type 2 diabetes, and dementia, thereby contributing to a decline in both quality of life and life expectancy (8). Furthermore, global increases in high fasting plasma glucose and its sequelae, type 2 diabetes, have mirrored the increases seen in BMI over the past 3 decades (9). Other behavioral risks (eg, unhealthy diet, physical inactivity, inadequate sleep, excessive alcohol use); environmental risks (eg, air pollution, extreme temperatures); and social risks (eg, house and food insecurity) also contribute to increased CVD burden and disparities in cardiovascular morbidity and mortality (10).

Several of the contextual risk factors attributed to increased CVD burden are covered in this special collection. Cigarette smoking persists among adults with chronic disease. Using data from the 2019 National Health Interview Survey (NHIS), Loretan and colleagues reported that more than 1 in 4 US adults aged 18 to 64 years with 1 or more chronic diseases associated with smoking were current smokers (11). The current cigarette smoking prevalence in the US reached 51.9% among adults aged 18 to 44 years with 2 or more chronic diseases (11). Furthermore, that study showed that smoking cessation services were not being provided to almost 1 in 3 people who have a chronic disease, leaving important steps to be taken toward successful smoking cessation in this population (11). Also concerning, rates of smoking vary significantly across countries, and approximately 1 billion people smoke globally, with significant negative implications for cardiovascular health (3). Goulding and colleagues used National Health and Nutrition Examination Survey data collected from 2011 through 2018 to provide estimates of the prevalence of high blood pressure among US children aged 8 to 17 years. The authors documented that elevated blood pressure was most prevalent

among children who were older, male, or non-Hispanic Black, with factors beyond inequalities in body weight likely contributing to disparities in elevated blood pressure (12). Furthermore, a meta-analysis conducted by Qie and colleagues determined that a high level of HDL-C may provide a protective effect on the risk of total stroke and ischemic stroke but may increase the risk of intracerebral hemorrhage (13). Another meta-analysis by Zhang and colleagues found an L-shaped dose-response relationship between circulating vitamin D levels and the risk of hypertension; however, the pooled results of randomized controlled trials did not show vitamin D supplementation to be effective in preventing hypertension (14).

Studies in this collection also identified populations and communities with higher prevalence or at higher risk for CVD. In a cross-sectional study using 2018 NHIS data, Mendez and colleagues documented a higher prevalence of CVD and its risk factors among US adults with vision impairment (15). Salahuddin and colleagues documented zip code variations in infant mortality rates associated with a high prevalence of maternal cardiometabolic high-risk conditions (chronic or gestational diabetes, chronic or gestational hypertension, smoking during pregnancy, and prepregnancy obesity) in 2 counties in Texas (16). Findings from these articles could direct efforts to implement appropriate strategies to prevent, manage, and control CVD in populations at high risk.

## Exploring Factors Contributing to Disparities in CVD

CVD and its related risk factors are increasingly recognized as growing indicators of global health disparities (17). Globally, differences in morbidity and mortality from CVD exist among high-, middle-, and low-income countries and across ethnic groups (1,3,5,6,17,18). In the US, disparities in CVD morbidity, mortality, and risk factors have persisted for decades, with concerning stagnation and significant upward trends since the early 2000s (18). Disparities are largely influenced by demographic, socioeconomic, and environmental factors (19,20). For example, African American and American Indian adults experience a higher burden of cardiovascular risk factors and CVD compared with non-Hispanic White adults (18). Unfortunately, structural racism remains a significant cause of poor cardiovascular health, restricting racial and ethnic minority populations from opportunities to live healthier lives, in healthier neighborhoods, and from access to quality education and health care (20).

Several studies in this collection examine the relationship between sociodemographic characteristics, including race, ethnicity, and geography, and CVD disparities. Within this broad topic, Tong and colleagues examined data on more than 1 million Medicare

fee-for-service beneficiaries aged 66 years or older hospitalized with a primary diagnosis of acute ischemic stroke (AIS). They identified significant racial, ethnic, and geographic variations in 5-year survival rates after AIS, with African American men and people living in the state of Hawaii having the lowest survival rate (21). Flynn and colleagues examined data from the National Vital Statistics System and documented marked differences in geographic patterns when using relative and absolute indicators of disparity as an appropriate measure for programs designed to decrease stroke mortality among US adults aged 35 to 64 years (22). This finding demonstrates the need to examine both measures of disparities along with race-specific rates when prioritizing efforts to eliminate racial inequities in stroke mortality (22). Furthermore, multiple factors affect the overall and cardiovascular health of rural residents (23). Hospital and outpatient facility care, clinician supply, insurance coverage, and public health infrastructure all differ between urban and rural areas, worsening disparities in CVD morbidity and mortality prominently observed among people living in rural areas (23). Tshiswaka and colleagues provide a geocoding snapshot that documents disparities in the availability of stroke centers in Florida, favoring urban counties and underscoring the need for equitable resource allocation regarding the availability of primary stroke centers in this state (24).

Available evidence suggests that influenza vaccination is associated with a protective effect in CVD morbidity and mortality (25). By using data from the Behavioral Risk Factor Surveillance System, Parekh and colleagues highlight the association of race and ethnicity and geographic location with disparities in influenza vaccination coverage among adults with CVD in the US, recommending prioritization of vulnerable populations looking beyond clinical settings as a place of vaccination (26). Compounding the challenge of seasonal influenza infection, the COVID-19 pandemic — another viral respiratory infectious disease — has exacerbated the health conditions of people with CVD worldwide and intensified disparities in CVD mortality rates in the US (6). In the US, African American, Hispanic, and Asian American populations experienced a disproportionate rise in deaths caused by heart disease and stroke, suggesting that these groups have been most impacted by the COVID-19 pandemic (6). In this collection, Tong and colleagues used data from a multistate stroke registry to examine the effect of the pandemic on stroke quality of care and demonstrated that, despite reductions in stroke hospitalizations and increased in-hospital death during the early phases of the pandemic, the adherence to quality of stroke care did not change much (27).

This collection also offers multiple recommendations and tools to identify SDOH and address disparities in CVD. For example, Le and colleagues introduce a powerful interactive visualization tool to identify county-level death rates and trends for several CVD

outcomes by different sociodemographic characteristics. This online dashboard provides maps, line plots, and charts useful for health practitioners and community leaders to identify and address health inequities in CVD mortality (28). Taken together, the variations identified across different geographic, racial, or ethnic groups, as described in this theme of the collection, call for urgent actions to address disparities to understand the reasons for these variations (eg, inequities in access to care and receiving treatments). Results indicate that addressing SDOH, including equitable availability and accessibility of resources, is necessary to mitigate the factors that influence the development of CVD disparities.

## Using Community-Based Approaches to Decrease CVD Risk

Decreasing CVD risk requires strong, diverse collaborations and the implementation of innovative approaches that aim to eliminate health disparities and advance health equity in diverse environments and contexts. Eliminating health disparities and advancing health equity should be core components in all research, evaluation, and programmatic activities and require a focus on SDOH (29). Systematically addressing SDOH requires multisectoral commitment and the implementation of evidence-based public policies and actions across all sectors. Countries that employ multisectoral approaches are better able to identify and address issues around poverty, housing, and others by working collaboratively across sectors, with multisectoral action by governments to achieve health equity (30).

Several studies in this collection identify strategies for community-based interventions that aim to reduce CVD disparities. For example, Long and colleagues evaluated 3-year sodium reduction initiatives in 3 community meal programs in Arkansas (31). Jordan and colleagues demonstrated the differential effects of sodium reduction strategies in food service settings by tailoring community-level approaches based on a community's available resources, stage of readiness, and food service staff's level of engagement (32). These studies show the effectiveness and sustainability of the implementation of sodium reduction interventions in reducing CVD in communities experiencing food insecurity, low incomes, and high risk for hypertension (31,32). The work from Smith and colleagues in Arkansas examines the benefits of using trusted community spaces such as barber and beauty shops for screening for chronic health conditions including blood pressure monitoring. Their findings indicate that community-based settings are effective in increasing knowledge of CVD-related risk factors and access to health promotion resources to reach minority populations (33).

Furthermore, both Stupplebeen and Sreedhara and their colleagues explored their experiences in implementing self-measured blood pressure monitoring and telehealth to address hypertension (34,35). Readers can draw from their experiences to make improvements to their hypertension control programs and initiatives. Finally, Stanhope and colleagues conducted qualitative interviews in the midst of the pandemic with postpartum patients who had a hypertensive disorder of pregnancy. Their work elaborates on the need to improve the uptake of preventive behaviors among postpartum patients at risk for heart disease through continuity and content of care improvements (36).

Collaborative innovations are beneficial to prevent, manage, and control CVD and risk factors. For example, as described by Abbas and colleagues, several clinicians and health care organizations were able to accelerate innovation and adapt services to maintain hypertension control among their high-risk populations during the COVID-19 pandemic, informing future collaborative efforts related to hypertension control during and after a public health emergency (37). Furthermore, as highlighted by Ramalingam and colleagues from their work in India, there is a need to invigorate and transform the public health workforce to prevent and control noncommunicable diseases. They do so through the innovative Field Epidemiology Training Program in noncommunicable diseases, which enhances workforce capacity in CVD epidemiology, surveillance, and evaluation to inform CVD control programs and policies. For instance, in India, resident projects focus on investigating aspects of hypertension epidemiology and management in collaboration with local partners (38). These types of community-based approaches can help to transform the social and environmental conditions affecting traditionally marginalized populations affected by CVD.

## Summary of Key Findings

The authors in this collection share lessons learned that represent experiences in diverse aspects of CVD prevention, management, and control. Their work highlights the multiple contextual health-related behaviors and cardiometabolic risk factors attributed to increased CVD burden. Studies in the collection discussed prevention strategies to optimize health behaviors to reduce the development of CVD risk factors or to avert the development or progression of disease. This collection also takes a view of pervasive disparities in the prevention and control of CVD and underscores the challenge and need to reposition evidence-based strategies to confront disparities.

Strategies described in this special collection such as telemedicine, engaging patients in self-measured blood pressure monitoring, adapting or implementing medication management services, activat-

ing partnerships, expanding services to respond to patient needs, and implementing unique patient outreach approaches also proved promising. Furthermore, tools and resources presented in this collection can be adapted to identify and address SDOH through tailored strategies, programs, and policies that can address the needs of populations disproportionately affected by CVD.

Nevertheless, much work remains to be done to address other factors contributing to CVD beyond those presented in this special collection, including the reasons for identified disparities in CVD and specific strategies to confront them, and to explore the intertwined effects of traditional risk factors, health care access, and SDOH on CVD risk and risk reduction. To address SDOH, efforts may need to be directed toward improving data systems to systematically measure SDOH, including racism and the social and psychological determinants affecting populations at higher risk or with higher incidence of disease, in a timely, relevant, and actionable manner. In addition, a major gap identified among articles appearing in the collection is the lack of focus, research questions, or emphasis on the impact of racism on cardiovascular health. Evidence has shown the significant impact of structural racism on poor health and premature death due to heart disease and stroke (20,39,40). Other areas not explored in this collection that deserve further examination include the lack of evidence on the long-term impact of COVID infection on the risk and burden of CVD, effects of COVID vaccinations in CVD management, and assessments of cardiovascular health globally.

## Implications

The articles in this collection reflect the magnitude of CVD and its risk factors across the globe. Preventing, managing, and controlling CVD will require the collective effort of policy and decision makers, clinical and public health practitioners, and researchers. Cardiovascular health may be improved by focusing on decreasing disparities in CVD, advancing health equity, and addressing SDOH. This collection of articles suggests that evidence-based and multicomponent interventions are necessary to address inequities and advance health equity. Furthermore, findings from this collection can be used to guide the development of community-based interventions to reduce cardiovascular disparities that are culturally appropriate, with a focus on health equity. Future research and evaluation of programs should focus on developing practical and innovative strategies, identifying and overcoming the barriers to access to quality care, and applying a health equity lens to accelerate advances in CVD prevention and control at the community, state, national, and global levels.

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## Author Information

Corresponding Author: Fátima Coronado, MD, MPH, Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy, MS S107-1, Atlanta GA 30341 (fec2@cdc.gov).

Author Affiliations: <sup>1</sup>National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia. <sup>2</sup>Institute for the Advancement of Minority Health, Ridgeland, Mississippi. <sup>3</sup>Department of Social Sciences and Health Policy, Wake Forest University School of Medicine, Winston-Salem, North Carolina.

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## SYSTEMATIC REVIEW

# Effect of Vitamin D on Blood Pressure and Hypertension in the General Population: An Update Meta-Analysis of Cohort Studies and Randomized Controlled Trials

Dongdong Zhang, MD<sup>1</sup>; Cheng Cheng, MD<sup>2</sup>; Yan Wang, MD<sup>1</sup>; Hualei Sun, MD<sup>1</sup>;  
Songcheng Yu, MD<sup>1</sup>; Yuan Xue, MD<sup>1</sup>; Yiming Liu, MD<sup>1</sup>; Wenjie Li, MD, PhD<sup>1</sup>; Xing Li, MD<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

The effects of vitamin D on hypertension risk and blood pressure have been explored widely in cohort studies and randomized controlled trials (RCTs), but whether the association is causal still is unknown.

**What is added by this report?**

We performed an update meta-analysis of both cohort studies and RCTs in a generally healthy population and found that the dose-response relationship between circulating 25-hydroxyvitamin D level and hypertension risk was approximately L-shaped. However, pooled results of RCTs showed that there was still no significant reduction in systolic and diastolic blood pressure.

**What are the implications for public health practice?**

Vitamin D supplementation is ineffective to prevent hypertension.

## Abstract

**Background**

The effect of vitamin D supplementation on blood pressure has been explored in previous meta-analyses, but whether the association is causal in the general population is still unknown. We evaluated the association comprehensively and quantitatively.

**Methods**

We searched PubMed and Embase for relevant cohort studies and randomized controlled trials (RCTs). We used a 2-step generalized least-squares method to assess the dose-response association of circulating 25-hydroxyvitamin D (25[OH]D) and hypertension and a fixed-effects model to pool the weighted mean differences (WMDs) and corresponding 95% confidence intervals (95% CIs) of blood pressure across RCTs.

**Results**

We identified 11 cohort studies and 27 RCTs, with 43,320 and 3,810 participants, respectively. The dose-response relationship between circulating 25(OH)D levels and hypertension risk was approximately L-shaped ( $P_{\text{nonlinearity}} = .04$ ), suggesting that the risk of hypertension increased substantially below 75 nmol/L as 25(OH)D decreased, but it remained significant over the range of 75–130 nmol/L. However, pooled results of RCTs showed that there was no significant reduction in systolic blood pressure (WMD,  $-0.00$  mm Hg; 95% CI,  $-0.71$  to  $0.71$ ) or diastolic blood pressure (WMD,  $0.19$  mm Hg; 95% CI,  $-0.29$  to  $0.67$ ) after vitamin D intervention.

**Conclusions**

The results of this meta-analysis indicate that supplementation with vitamin D does not lower blood pressure in the general population. RCTs with long-term interventions and a sufficient number of participants who have low levels of vitamin D are needed to validate these findings.

## Introduction

Emerging evidence suggests that vitamin D deficiency is a widespread global problem (1). According to the Institute of Medicine (IOM), vitamin D deficiency is defined as circulating 25-hy-

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droxyvitamin D (25[OH]D) level <50 nmol/L based on the optimal concentration for skeletal health (2). Interest has increased concerning the potential health consequences of vitamin D deficiency, such as increased risk of cardiovascular diseases, cancers, and Alzheimer's disease (3–5). Although observational data have demonstrated that poor vitamin D status is associated with increased risk of hypertension (6–9), randomized controlled trials (RCTs) have provided little support for the beneficial effect of vitamin D supplementation on blood pressure (10–13). Considering the potential residual confounding, inferring causality or reversibility of this relationship and reaching consensus from these findings is difficult.

Several meta-analyses of observational studies and RCTs have been published, but results are conflicting (14–17). Golzarand et al evaluated 30 RCTs with 4,744 participants and concluded that vitamin D has a beneficial effect in subgroups of daily doses >800 IU/d, a duration less than 6 months, or older subjects (14). Kunutsor et al suggested that supplementation with vitamin D significantly reduced diastolic blood pressure (DBP) by 1.31 mm Hg in participants with preexisting cardiometabolic conditions (16). However, another meta-analysis performed by incorporating individual data supported that vitamin D supplementation is ineffective in lowering blood pressure (15).

Taken together, it may be hypothesized that the increased blood pressure or risk of hypertension is partly explained by individuals' baseline vitamin D status, the sample size, the intervention dose, and the follow-up duration. Meanwhile, considering that pre-existing conditions such as diabetes, cardiovascular disease, and kidney disease may influence the physiologic mechanism of vitamin D on blood pressure, considerable variability may exist between individual patients and the general population. Therefore, restricting the participants to the general population may help to explore the true association hidden by the confounders. Analyzing the population as a whole rather than restricting analyses to certain population subgroups may help us to explore the true association hidden by confounders. In addition, results from at least 10 more studies including 1,716 participants have been published on this topic since the latest meta-analysis in 2015 (10–12,18–24).

We aimed to provide a comprehensive and quantitative meta-analysis from the published cohort studies and RCTs on the effect of vitamin D involving hypertension risk and blood pressure levels in the general population.

## Methods

We used the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) checklist to perform the meta-analysis and report the results (25).

### Data source and searches

We searched PubMed and Embase databases up to June 12, 2019, for cohort studies reporting an association between blood 25(OH)D levels and risk of incident hypertension and for RCTs examining the effect of vitamin D supplementation (alone or in combination with other nutrients) on blood pressure. The search terms “vitamin D” and “blood pressure” were used in combination to retrieve relevant records. The records were restricted to human studies, and additional studies were retrieved through manually searching the references of identified articles and relevant systematic reviews.

### Study selection

Two investigators (D.Z. and C.C.) reviewed the titles and abstracts independently to identify articles for potentially relevant sources. Full-text versions were requested to evaluate eligibility. To be included, the study had to meet the following criteria: 1) followed an RCT or a cohort study design; 2) investigated the association between vitamin D and risk of hypertension or effect of blood pressure levels; 3) included a general population ( $\geq 18$  y) rather than patients with specific diseases (eg, diabetes, hypertension, stroke, heart failure); and 4) provided estimates of the risks of hypertension in at least 3 categories of blood 25(OH)D levels or reported continuous risk estimates for the dose–response analysis, or reported blood pressure for meta-analysis of RCTs. We excluded articles if they 1) measured other metabolites of vitamin D (eg, 1,25-dihydroxyvitamin D); 2) focused on pregnant women or groups with specific diseases; or 3) did not report blood pressure at baseline/end or the changes after intervention from baseline for trials. Inconsistencies were resolved through group discussion or adjudicated by a third reviewer.

### Data extraction

Using predefined protocols, D.Z. extracted data from each study and C.C. checked the accuracy. For cohort studies, the following information was abstracted: first author, publication year, country, follow-up period, sample size, age, number of cases/participants, categories of 25(OH)D levels, reported risk estimates, 95% confidence intervals (CIs), and covariates adjusted for in the analyses. When several adjusted models were explored, we extracted the risk ratios from the model with largest number of covariables. If the lowest 25(OH)D level was not the reference, we recalculated the risk estimates by the method of Hamling et al (26). When the mean or median 25(OH)D level per category was not reported, we assigned the value as the midpoint of the lower and upper bound in each category (27). If the category was open-ended, we assumed the width of interval to be the same as in the adjacent category (27). If studies reported 25(OH)D levels in ng/mL, we converted the values to nmol/L by multiplying by 2.5.

For RCTs, we recorded the following data: study design (sample size of each group, blinding methods, intervention/placebo type and amount, duration of intervention, type of vitamin D, and intervention frequency); characteristics of participants (age, sex, baseline circulating 25[OH]D levels); and baseline/end blood pressure in both intervention and placebo groups and/or blood pressure changes from baseline. If studies used different doses of vitamin D, we extracted only the highest dose in the analysis. If studies measured blood pressures repetitively at different intervals during the intervention, we included only the blood pressure values at the longest follow-up point. Attempts were made to contact corresponding authors for unavailable information.

### Risk for bias assessment

We used the 9-star Newcastle–Ottawa Scale to evaluate the quality of individual cohort studies; the scale is based on 8 aspects covering selection, comparability, and outcome domains (28). Meanwhile, we assessed the risk of bias for each trial using 7 fields from The Cochrane Collaboration’s tool: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias (29). Summary assessments for trials were assigned as “high,” “low,” or “unclear,” according to the risk bias in each outcome. Disagreements were resolved through group discussion. Publication bias was assessed with Egger’s test (30).

### Data synthesis and analysis

To provide dose–response evidence from all cohort studies, we used the 2-step generalized least-squares method (31). Study-specific slope coefficients were examined by restricted cubic splines with three knots at 25%, 50%, and 75% of the distribution of circulating 25(OH)D levels. For the dose–response analyses of 25(OH)D, the reference category was re-scaled to 75 nmol/L, which is the cutoff value between insufficient and sufficient vitamin D status. *P* values for nonlinearity were calculated by using the Wald  $\chi^2$  test, assuming the coefficient of the second spline was zero. We used the DerSimonian and Laird random effects model to estimate the study-specific dose–response risk, and we calculated the pooled risk of hypertension for every 25 nmol/L increment in 25(OH)D levels using a random effects model (32).

We assessed the effect of vitamin D supplementation by the mean blood pressure changes (including systolic blood pressure [SBP] and DBP) in the intervention group minus the changes in blood pressure in the placebo group. The standard deviations (SDs) were obtained as reported or calculated from 95% CIs, *P* values for *t* statistics, or individual standard errors (SE) from intervention and placebo groups. If the studies did not report blood pressure

changes from baseline, we calculated the mean values by using blood pressure after intervention minus blood pressure at baseline, and the SD of changes was obtained according the following formula, described in the *Cochrane Handbook for Systematic Reviews of Interventions* (29):

$$SD_{\text{change}} = \sqrt{SD_{\text{baseline}}^2 + SD_{\text{final}}^2 - (2 \times \text{Corr} \times SD_{\text{baseline}} \times SD_{\text{final}})}$$

We estimated correlation by calculations from 2 studies that provided complete data for  $SD_{\text{baseline}}$ ,  $SD_{\text{final}}$ ,  $SD_{\text{change}}$  in both intervention and placebo groups (33,34). Between-study heterogeneity was assessed with the  $I^2$  and *Q* statistics. We used fixed-effects models and forest plots to pool the weighted mean differences (WMDs) and corresponding 95% CIs of blood pressure across studies.

Predefined subgroup analyses were performed to explore potential effect modification and sources of heterogeneity. We also conducted sensitivity analyses by removing one study at a time to ensure that the pooled result was not simply dependent on one large or individual case. All statistics were analyzed using Stata, version 12.1 (StataCorp, LLC). Significance was set at  $P < .05$ .

## Results

### Descriptive study characteristics

The systematic search in PubMed and Embase retrieved 8,956 publications, and 3 more were identified by manual searching. After duplicate checking and initial review of the titles and abstracts, 156 potentially relevant articles were obtained in full text for further evaluation. Finally, 119 articles were excluded and 37 publications (including 11 cohort studies in 10 publications [6–9,35–40] and 27 trials [10–13,18–24,33,34,41–54]) were eligible for inclusion.

Eleven cohort studies with 8,397 incident cases of hypertension and 43,320 participants were identified from 10 publications. With the exception of 1 study conducted in Asia, most were conducted in Europe ( $n = 4$ ) and the United States ( $n = 6$ ). The follow-up durations ranged from 1.3 to 15.3 years (median 5.0 years). Analyses of the quality of studies yielded an average NOS score of 7.5, nine of which were of high quality (score  $\geq 7$ ).

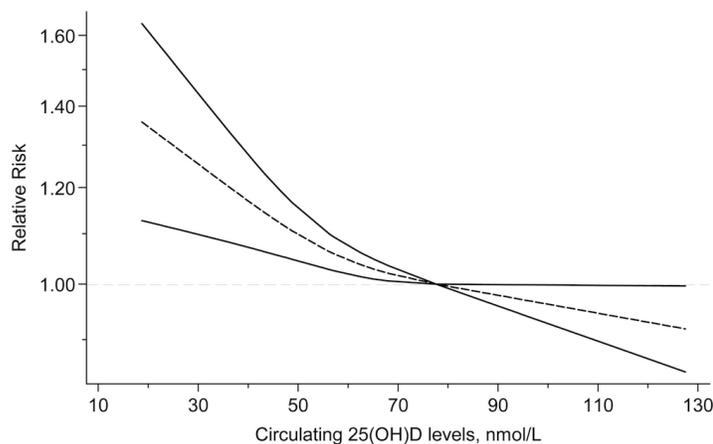
Twenty-seven studies were RCTs with 3,810 participants. Among them, 2 studies included only men, 10 included only women, and 15 included both. Five of the included trials were conducted in Asia, 12 were performed in Europe, 4 were conducted in Oceania, and the remaining 6 were performed in the United States. Mean or median baseline 25(OH)D concentrations varied from 25.6 nmol/L to 78.0 nmol/L, and 11 studies investigated the effects in individu-

als with vitamin D insufficiency, vitamin D deficiency, or both. Nine trials did not provide the final 25(OH)D concentration in intervention arms, whereas the remaining studies showed a substantial increase in circulating levels of 25(OH)D compared with the baseline assessment. All trials had low risk of bias for random allocation and selective reporting. There was insufficient information about allocation concealment in 5 trials and high risk of bias in 1 trial. One open-label trial had high risk of bias for blinding of participants and personnel and unclear bias risk for blinding of outcome assessment (43).

## Meta-analyses results

### Circulating 25(OH)D levels and hypertension risk

Quantitative results from meta-analyses of cohort studies showed that the risk of incident hypertension decreased by 7% (relative risk [RR] = 0.93; 95% CI, 0.89–0.98) per 25 nmol/L increment in 25(OH)D levels, with significant heterogeneity ( $I^2 = 61.6\%$ ,  $P_{\text{heterogeneity}} = .004$ ). Ten studies reporting RR for 25(OH)D exposures in at least 3 levels were eligible for the linear trend estimation. Results from the analysis of restricted cubic splines indicated an approximate L-shaped correlation between circulating 25(OH)D levels and hypertension risk ( $P_{\text{nonlinearity}} = .04$ , Figure 1). The risk of hypertension increased substantially below 75 nmol/L as 25(OH)D decreased but remained significant over the range of 75–130 nmol/L.



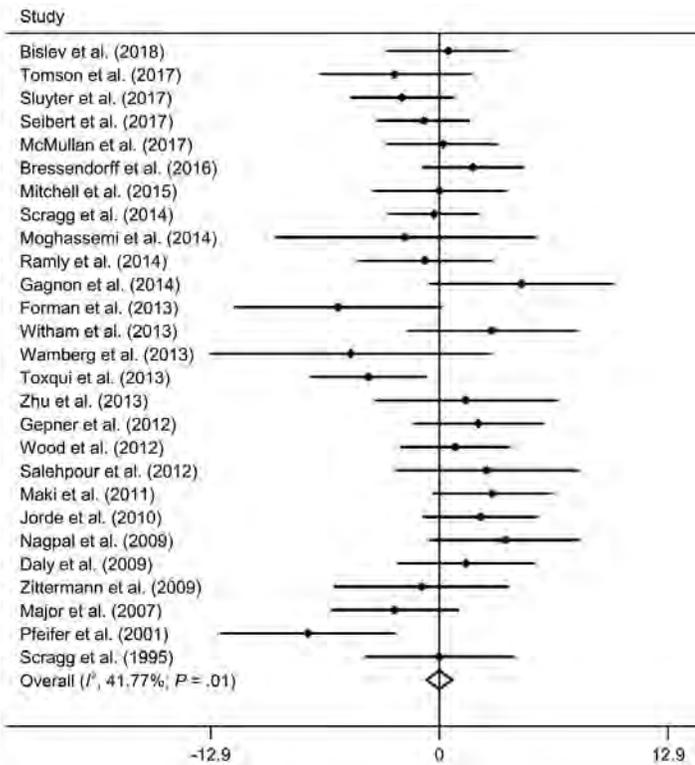
**Figure 1.** Nonlinear dose–response association between circulating 25(OH)D levels and hypertension risk, update meta-analysis of cohort studies of the effect of 25(OH)D levels on hypertension in the general population. The dashed line indicates the pooled restricted cubic spline model, and the solid lines indicate the 95% CIs of the pooled curve. Abbreviations: 25(OH)D, 25-hydroxyvitamin D; CI, confidence interval.

Subgroup analyses indicated sex (male, female, or mixed), follow-up duration ( $\leq 5$  y or  $> 5$  y), region (America, Europe, or Asia), number of cases ( $< 1,000$  or  $\geq 1,000$ ), and study quality (high, me-

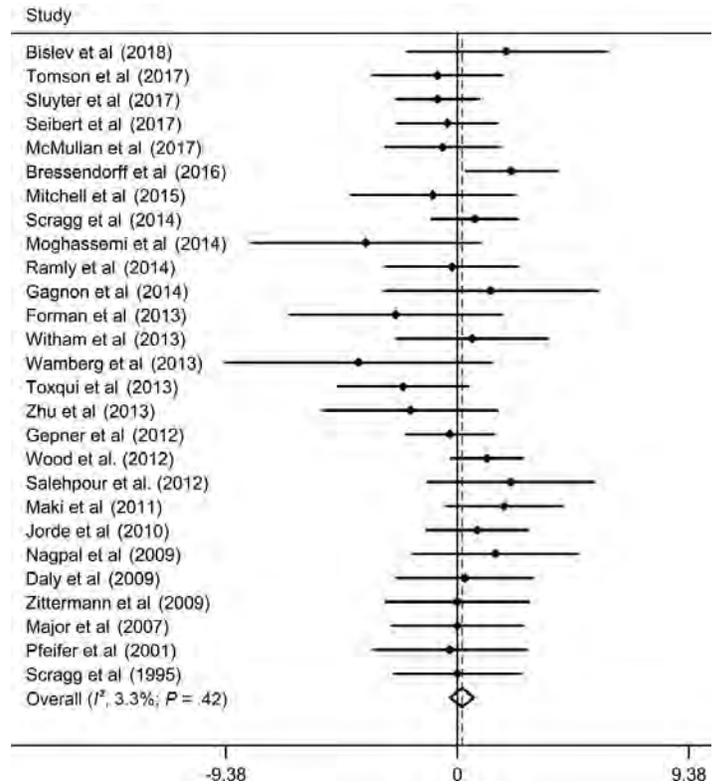
dium, or low) as the potential sources of the heterogeneity (Table 1). However, the association of 25(OH)D levels per 25 nmol/L increment showed no significance in subgroups of men (RR = 0.93; 95% CI, 0.85–1.00), women (RR = 0.88; 95% CI, 0.76–1.01), European region (RR = 0.97; 95% CI, 0.94–1.01), small number of cases (RR = 0.95; 95% CI, 0.89–1.02), and medium or low quality of study (RR = 0.91; 95% CI, 0.80–1.03). Furthermore, the pooled estimates could not be altered substantially by removing one study at a time, and we found no evidence of publication bias by Egger’s test ( $P = .38$ ).

### Vitamin D supplementation and blood pressure levels

Figures 2 and 3 present the forest plots for effect of vitamin D supplementation on SBP and DPB across the included 27 trials. Overall, vitamin D supplementation did not have a significant effect on SBP reduction (WMD,  $-0.00$  mm Hg; 95% CI,  $-0.71$  to  $0.71$ ), with evidence of low heterogeneity ( $I^2 = 41.7\%$ ,  $P_{\text{heterogeneity}} = .01$ ). There was also no significant reduction in DBP after intervention, and the WMD (95% CI) was  $0.19$  mm Hg ( $-0.29$  to  $0.67$ ), without evidence of significant heterogeneity ( $I^2 = 3.3\%$ ,  $P_{\text{heterogeneity}} = .42$ ).



**Figure 2.** Meta-analysis of effect of vitamin D supplementation on systolic blood pressure, update meta-analysis of randomized controlled trials of the effect of vitamin D on blood pressure in the general population. Abbreviations: CI, confidence interval; WMD, weighted mean difference.



**Figure 3.** Meta-analysis of effect of vitamin D supplementation on diastolic blood pressure, update meta-analysis of randomized controlled trials of the effect of vitamin D on blood pressure in the general population. Abbreviation: WMD, weighted mean difference.

Table 2 shows the subgroup analyses of summary WMDs in SBP and DBP. We found that the heterogeneity decreased in studies of men, studies with overweight or obese individuals, studies with a large sample size ( $\geq 200$ ), and studies with an intervention duration of 6 months or longer. The effects of vitamin D supplementation on SBP and DBP was still insignificant in all subgroups. In sensitivity analyses, the summary results remained similar by removing one study at a time. According to Egger's test, we found no evidence of publication bias in studies of SBP ( $P$  = .60) and DBP ( $P$  = .07).

## Discussion

This meta-analysis of cohort studies suggested an inverse association between 25(OH)D levels and incident hypertension, with hypertension risk reduced by 7% per 25 nmol/L increment in 25(OH)D levels. Meanwhile, summary data of RCTs indicated no evidence of blood pressure reduction by supplementation with vit-

amin D, a finding consistent with subgroup analyses based on baseline overweight/obese status, baseline 25(OH)D level, follow-up duration, and intervention dose.

The findings from numerous observational studies have shown that sufficient vitamin D status is a protective factor for hypertension. Analysis of Mendelian randomization also provided the causal evidence for the effect of increased circulating 25(OH)D levels on reduced blood pressure levels and risk of hypertension (55). However, our subgroup analyses of the cohort studies produced inconsistent results, which indicated that the quantitative data failed to provide convincing evidence of the protective effect of vitamin D on hypertension. Meanwhile, most of the interventional studies did not provide consistent evidence of blood pressure benefit from supplementing with vitamin D (11–13,21,49,50,53). Given these findings, we speculate that the beneficial effect observed in cohort studies may be partly explained by the tendency that sufficient vitamin D levels are closely related to healthy lifestyle or study participants being young. It may be also in part because of the hypothesis that low 25(OH)D levels could be the result of sub-health status rather than a precursor of diseases. Furthermore, differences exist among the various methods used (ie, liquid chromatography-mass spectrometry; high-performance liquid chromatography; and enzymoimmunoassay, radioimmunoassay, and chemiluminescence immunoassays) and in the laboratories that measured 25(OH)D levels, which would also influence the accuracy of the study results (56).

Similar with our results, previous meta-analyses also showed no overall lowering effect of vitamin D supplementation on blood pressure (14–16,57). However, they suggested that vitamin D may show a beneficial effect on blood pressure in specific subgroups, such as older people, people whose dosage of vitamin D was high (>800 IU/d), short-term interventions (<6 months), or individuals with pre-existing cardiometabolic disease (14,16). A possible reason for this discrepancy is that the recruited populations of included studies had high heterogeneity. Therefore, we restricted this meta-analysis to analyses of apparently healthy individuals. We excluded trials that have targeted patients with hypertension, diabetes, cardiovascular disease, or other diseases, because the known or unknown interaction between vitamin D and antihypertensive or cardiovascular medications may mask or attenuate the small effects of blood pressure reduction.

Complicated factors such as baseline vitamin D status, intervention design, or adiposity may modify or blunt the beneficial effect on blood pressure of improving vitamin D levels. An increasing body of evidence supports the presence of thresholds in vitamin D status (58). Similarly, the approximately L-shaped relationship between 25(OH)D levels and hypertension risk in our meta-analysis showed that hypertension risk increased substantially below

75 nmol/L but remained marginally significant above 75 nmol/L, which suggests that subjects with vitamin D insufficiency or deficiency show higher response to supplementation. In addition, evidence showed a therapeutic effect of cholecalciferol only in vitamin D-depleted participants by decreasing their 24-hour blood pressure by 3–4 mm Hg (59). Therefore, we speculated that the protective effect would only appear in subjects with low vitamin D levels. Indeed, we classified the studies according to their baseline vitamin D status, but the results indicated that vitamin D supplementation had no apparent effect on blood pressure, regardless of its baseline status. This finding is in accord with a recent meta-analysis that used individual patient data (15). However, considering that the number of people with low vitamin D levels may be insufficient in our study, further trials are needed to verify this finding.

Individuals who are taking vitamin D supplements should do so for at least 6 months to reach the maximum attained 25(OH)D level (60). It is reasonable to assume that the effect of vitamin D is time-dependent. However, our findings from subgroup analyses of RCTs suggested that response of blood pressure to vitamin D is independent of interventional duration (<6 months and ≥6 months). Similar findings have been reported (16,61). Considering these findings, we still cannot rule out that the duration of vitamin D intervention is insufficient to detect any slight but significant reduction in blood pressures, especially in the apparently healthy subjects whose normal values are less likely to be further improved. It is worth noting that until June 2019 only one RCT lasting up to 2 years was included in our study; therefore, a protective effect of longer intervention could not be studied adequately. Future RCTs with longer follow-up duration are needed to provide in-depth insight into the long-term benefits of vitamin D supplementation.

The optimal dose for vitamin D supplementation would influence the effect on blood pressure. A 4-arm trial conducted in African Americans reported dose-dependent reductions in SBP after 3 months of cholecalciferol supplementation with 1,000 IU, 2,000 IU, and 4,000 IU per day (0.66 mm Hg, 3.4 mm Hg, and 4.0 mm Hg, respectively) (34). In addition, a meta-analysis synthesizing the results of 30 RCTs suggested that vitamin D supplementation at a dose of >800 IU/d reduced blood pressures significantly (14). Contrary to these results, we did not find the dose–response relationship for vitamin D on blood pressure. We should consider the possibility that the supplementary doses in most included trials may be larger or smaller to observe a beneficial effect. Further studies are needed to explore the potential quantitative model.

This meta-analysis of RCTs included 3,810 people from the general population, which provides a substantial statistical power to detect the potential effects and thereby enhances the generalizability of our findings. However, our study also contains several poten-

tial limitations. First, because most studies did not record the changes of diet, sun exposure or latitudes, genetic factors, and educational status, we are not able to answer the questions of whether these factors would modify the effect of the intervention. Second, there are several trials that did not reach enough power (they were below 80%) to detect any weak difference between interventional and placebo groups because of the small sample size and high rate of noncompliance (13,20,53). In addition, although we stratified the duration of follow-up (the maximum is 2.0 years) and found no significant difference between subgroups, it remains unclear whether there are any long-term (>2 years) effects of vitamin D to improve blood pressure levels. However, we may conclude that vitamin D supplementation will not affect blood pressure short-term.

The results of this meta-analysis indicate that supplementation with vitamin D does not lower blood pressure in the general population. On the basis of this finding, we do not recommend using vitamin D supplementation to prevent hypertension. However, future RCTs with long-term interventions and sufficient sample sizes of people with low vitamin D levels are needed to replicate this finding.

## Acknowledgments

D.Z. and W.L. contributed to the conception of the original idea. C.C., D.Z., Y.W., and H.S. searched for studies and agreed on inclusion and exclusion. D.Z., C.C., and S.Y. extracted data and performed the data analysis. D.Z., Y.X., and Y.L. drafted the manuscript. All authors have read and approved the manuscript.

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## Author Information

Corresponding Authors: Wenjie Li, MD, PhD, Department of Nutrition and Food Hygiene, College of Public Health, Zhengzhou University, 100 Kexue Ave, Zhengzhou, 450001 Henan, China. Telephone: 86-371-6778-1305. Email: lwj@zzu.edu.cn.  
Xing Li, MD, Department of Nutrition and Food Hygiene, College

of Public Health, Zhengzhou University, 100 Kexue Ave, Zhengzhou, 450001, Henan, China. Telephone: 86-371-6778-1305. Email: lixing530@zzu.edu.cn.

Author Affiliations: <sup>1</sup>Department of Nutrition and Food Hygiene, College of Public Health, Zhengzhou University, Henan, China. <sup>2</sup>Department of Epidemiology and Health Statistics, College of Public Health, Zhengzhou University, Henan, China.

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## Tables

**Table 1. Subgroup Analyses for the Dose–Response Association Between Per 25 nmol/L Increment in Circulating 25-Hydroxyvitamin D and Hypertension Risk, Update Meta-Analysis of Cohort Studies, 2019**

Subgroup	No. of studies	No. of participants	RR (95% CI)	P value	I <sup>2</sup> , %
<b>Sex</b>					
Male	3	3,230	0.93 (0.85–1.00)	.06	28.7
Female	2	3,351	0.88 (0.76–1.01)	.07	0
Mixed	6	36,739	0.95 (0.89–1.00)	.06	76.4
<b>Region</b>					
United States	6	30,002	0.90 (0.83–0.97)	.006	65.1
Europe	4	10,862	0.97 (0.94–1.01)	.11	0
Asia	1	2,456	0.97 (0.90–1.05)	.44	–
<b>No. of cases</b>					
<1,000	6	5,696	0.95 (0.89–1.02)	.16	39.6
≥1,000	5	37,624	0.94 (0.91–0.96)	.02	77.1
<b>Duration, years</b>					
≤5	6	31,171	0.92 (0.84–1.00)	.06	73.9
>5	5	12,149	0.96 (0.93–0.99)	.01	0
<b>Study quality</b>					
High	7	18,488	0.96 (0.94–0.99)	.006	9.5
Medium or low	2	24,832	0.91 (0.80–1.03)	.13	87.0

Abbreviations: –, not applicable/not calculated; CI, confidence interval; RR, relative risk.

**Table 2. Subgroup Analyses of Vitamin D Supplementation and Blood Pressure Levels in the General Population, Update Meta-Analysis of Randomized Controlled Trials, 2019**

Subgroup	No. of Studies	No. of Participants	SBP			DBP		
			WMD (95% CI)	P	I <sup>2</sup> , %	WMD (95% CI)	P	I <sup>2</sup> , %
<b>Sex</b>								
Male	2	211	2.49 (−0.33 to 5.31)	.08	0	0.80 (−1.33 to 2.93)	.46	0
Female	10	1,215	−0.68 (−2.59 to 1.23)	.48	55.5	0.18 (−0.60 to 0.97)	.65	13.2
Mixed	15	2,384	0.11 (−0.81 to 1.02)	.82	28.6	0.14 (−0.49 to 0.76)	.66	11.7
<b>Age, y</b>								
<50	15	1,751	0.04 (−0.88 to 0.96)	.93	29.7	0.23 (−0.43 to 0.88)	.50	9.1
≥50	12	2,059	−0.27 (−2.01 to 1.48)	.76	55.5	0.15 (−0.55 to 0.84)	.68	4.0
<b>Region</b>								
United States	6	569	−0.01 (−2.17 to 2.14)	.99	50.3	−0.09 (−1.11 to 0.92)	.86	0
Europe	12	1,698	−0.61 (−2.20 to 0.97)	.45	52.9	0.42 (−0.27 to 1.11)	.23	19.1
Asia	5	469	1.24 (−0.87 to 3.35)	.25	0	−0.06 (−1.57 to 1.44)	.94	33.4
Oceania	4	1,074	−0.06 (−1.67 to 1.56)	.94	48.4	0.06 (−1.01 to 1.14)	.91	0
<b>Baseline obesity status</b>								
Overweight/obese	9	895	1.01 (−0.32 to 2.34)	.14	26.9	0.40 (−0.53 to 1.33)	.40	3.4
Not clear <sup>a</sup>	18	2,915	−0.41 (−1.25 to 0.43)	.34	44.4	0.11 (−0.44 to 0.67)	.69	7.3
<b>Baseline vitamin D status</b>								
Insufficient/deficient	11	924	−0.44 (−2.33 to 1.44)	.64	51.9	−0.08 (−0.83 to 0.99)	.86	31.3
Not clear <sup>a</sup>	16	2,886	−0.10 (−0.80 to 1.00)	.82	40.8	0.27 (−0.32 to 0.86)	.37	0
<b>Sample size</b>								
<200	22	2,240	−0.01 (−0.82 to 0.84)	.98	47.5	0.04 (−0.55 to 0.63)	.88	7.8
≥200	5	1,570	−0.03 (−1.41 to 1.35)	.96	13.5	0.46 (−0.35 to 1.28)	.27	0
<b>Type of vitamin D</b>								
Cholecalciferol	25	3,620	−0.01 (−0.76 to 0.73)	.98	46.2	0.25 (−0.24 to 0.74)	.32	7.3
Ergocalciferol	2	190	0.12 (−2.27 to 2.50)	.92	0	−0.73 (−2.63 to 1.17)	.45	0
<b>Frequency</b>								
Daily	18	2,053	−0.36 (−1.74 to 1.02)	.61	52.3	0.27 (−0.34 to 0.88)	.39	26.3
Weekly	3	416	0.91 (−0.99 to 2.81)	.35	0	−0.02 (−1.42 to 1.37)	.97	0
Fortnightly	1	71	3.69 (−0.49 to 7.87)	.08	—	1.54 (−1.81 to 4.89)	.37	—
Monthly	3	1,031	−1.02 (−2.71 to 0.67)	.24	0	−0.11 (−1.21 to 1.00)	.85	0
Single dose	2	239	1.30 (−1.84 to 4.43)	.42	0	0.25 (−1.72 to 2.21)	.80	0
<b>Duration<sup>b</sup></b>								
<6 months	15	1,330	−0.23 (−1.71 to 1.26)	.76	55.8	0.11 (−0.58 to 0.80)	.75	28.7

Abbreviations: —, not applicable/not calculated; CI, confidence interval; DBP, diastolic blood pressure; SBP: systolic blood pressure; WMD, weighted mean difference.

<sup>a</sup> “Not clear” is defined as articles that did not specify whether the subjects were overweight/obese or vitamin D insufficient/deficient.

<sup>b</sup> Total number of studies in the subgroup is not equal to 27, because 2 trials supplemented vitamin D by single dose (49,54).

<sup>c</sup> Total number of studies in the subgroup is not equal to 27, because 2 trials supplemented vitamin D with other mineral or multivitamin nutrient (44,45).

<sup>d</sup> This subgroup restricted to trials with daily administration.

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**Table 2. Subgroup Analyses of Vitamin D Supplementation and Blood Pressure Levels in the General Population, Update Meta-Analysis of Randomized Controlled Trials, 2019**

Subgroup	No. of Studies	No. of Participants	SBP			DBP		
			WMD (95% CI)	P	I <sup>2</sup> , %	WMD (95% CI)	P	I <sup>2</sup> , %
≥6 months	10	2,241	-0.02 (-1.15 to 1.12)	.98	20.9	0.26 (-0.44 to 0.97)	.47	0.0
<b>Intervention type<sup>c</sup></b>								
Vitamin D alone	18	2,774	0.16 (-0.69 to 1.00)	.72	0	0.25 (-0.30 to 0.80)	.38	6.0
Vitamin D + calcium	7	867	-0.65 (-3.66 to 2.37)	.68	70.4	-0.02 (-1.14 to 1.10)	.97	0
<b>Intervention amount<sup>d</sup></b>								
≤800 IU/d	6	619	-1.91 (-4.24 to 0.42)	.15	57.9	-0.66 (-1.75 to 0.43)	.51	0
>800 IU/d	12	1,434	0.87 (-0.30 to 2.05)	.15	30.1	0.69 (-0.05 to 1.42)	.07	33.1
<b>Risk of bias</b>								
Low	12	1,564	-0.39 (-1.50 to 0.72)	.49	41.4	0.23 (-0.55 to 1.00)	.56	0
High	7	1,166	0.03 (-2.34 to 2.41)	.98	63.1	-0.38 (-1.34 to 0.58)	.44	18.2
Unclear	8	1,080	0.74 (-0.49 to 1.97)	.24	7.0	0.53 (-0.26 to 1.32)	.19	8.2

Abbreviations: —, not applicable/not calculated; CI, confidence interval; DBP, diastolic blood pressure; SBP, systolic blood pressure; WMD, weighted mean difference.

<sup>a</sup> “Not clear” is defined as articles that did not specify whether the subjects were overweight/obese or vitamin D insufficient/deficient.

<sup>b</sup> Total number of studies in the subgroup is not equal to 27, because 2 trials supplemented vitamin D by single dose (49,54).

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<sup>d</sup> This subgroup restricted to trials with daily administration.

## PROGRAM EVALUATION BRIEF

# Self-Measured Blood Pressure Monitoring: Program Planning, Implementation, and Lessons Learned From 5 Federally Qualified Health Centers in Hawai‘i

David A. Stuppelbeen, PhD<sup>1</sup>; Catherine M. Pirkle, PhD<sup>1</sup>; Tetine L. Sentell, PhD<sup>1</sup>; Blythe M. I. Nett, MPH<sup>2</sup>;  
Lindsey S. K. Ilagan, MS<sup>2</sup>; Bryan Juan, MPH<sup>3</sup>; Jared Medeiros, APRN<sup>4</sup>; L. Brooke Keliikoa, DrPH<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

Self-measured blood pressure monitoring programs (BPMPs) are effective in helping people with hypertension control their blood pressure.

**What is added by this report?**

This article explores the experiences of 5 Hawai‘i-based Federally Qualified Health Centers (FQHCs) in implementing self-measured BPMPs. Because no nationally recognized self-measured BPMP curriculum existed at the time of this evaluation, the purpose of this article was to understand how FQHCs designed and implemented self-measured BPMPs in practice.

**What are the implications for public health practice?**

Policy makers, funding organizations, and intervention designers can draw on these experiences to make improvements to self-measured BPMPs in terms of support and toward the development of a standardized intervention curriculum.

## Abstract

Self-measured blood pressure monitoring programs (BPMPs) are effective at controlling hypertension. We examined implementation of self-measured BPMPs at 5 Hawai‘i-based Federally Qualified Health Centers (FQHCs). In a process evaluation of these programs, we found that FQHCs developed protocols for self-measured BPMP recruitment and enrollment and provided addi-

tional supports to account for their patients’ psychosocial needs to achieve blood pressure control, such as lifestyle change education and opportunities through referrals either to on-site or other programs (eg, on-site gym, tobacco cessation program). Common barriers across sites included insufficient material support for blood pressure monitors and data collection; funding, which affects program sustainability; and the lack of an “off-the-shelf” self-measured BPMP intervention. Policy makers and funding organizations should address these issues related to self-measured BPMPs to ensure implementation success.

## Background

Self-measured blood pressure monitoring programs (BPMPs) are interventions for patients to track their blood pressure at home or in other nonclinical settings. They are used to diagnose high blood pressure, improve blood pressure control, and reduce the risk of related conditions, including heart disease, heart attacks, and stroke (1). Compared with usual care, self-measured BPMPs can substantially decrease blood pressure versus usual care, especially when combined with additional support (2), including patient counseling (eg, medication management, lifestyle change), education on blood pressure management, or access to electronic monitoring tools (3). Program delivery can encompass team-based care and include telemonitoring with support from pharmacists or registered nurses (4,5). Implementing self-measured BPMPs in team-based care settings with other medical team members, such as community health workers (CHWs) (6), who work together with patients to achieve controlled blood pressure, is cost-effective (7).

## Purpose and Objectives

In 2014, the Centers for Disease Control and Prevention (CDC) awarded funds to the Hawai‘i Department of Health (HDOH),



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Hawai'i Primary Care Association (HPCA), and 9 Federally Qualified Health Centers (FQHCs) to increase use of self-measured BPMPs with clinical support (8). In 2015, Hawai'i FQHCs served more than 150,000 patients, 42.8% of whom were Native Hawaiian or other Pacific Islander (NHOPI) (9). More than three-quarters of patients had incomes below the federal poverty level in 2013 (10). Although 17,883 Hawai'i FQHC patients had hypertension in 2015, only 64% had achieved blood pressure control (9). NHOPIs face socioeconomic barriers to hypertension management (11) similar to other populations who use FQHC services (12). At the start of the grant, there was no CDC-approved standardized curriculum for self-measured BPMPs; thus, FQHCs developed their own protocols and programs as part of their grant deliverables. In this article, we describe the self-measured BPMP components at 5 Hawai'i-based FQHCs during the grant period to highlight barriers and facilitators to program implementation.

## Evaluation Methods

Evaluators from the University of Hawai'i at Mānoa were contracted to provide a process evaluation that qualitatively assessed common self-measured BPMP components and that assessed barriers and facilitators at sites implementing the program. HPCA identified 5 FQHCs with self-measured BPMPs at varying levels of maturity; these FQHCs represented different practice settings (rural or urban) and patient population sizes (small or large). Health centers selected staff familiar with their self-measured BPMPs to participate in semi-structured video or telephone interviews, conducted in June and July 2018. Nine providers participated (Table 1), and all interviewees provided written consent. Evaluators asked how self-measured BPMP participants were identified, recruited, and enrolled; how programs were implemented; how patients were monitored; and about program barriers and facilitators. Four calls were recorded and transcribed; contemporaneous notes were taken during the fifth call. Transcripts and notes were qualitatively coded in Nvivo 11 (QSR International) and the primary evaluator (D.S.) deductively grouped codes into themes to mirror a typical programmatic logic model (ie, inputs, activities, outputs, and short-/long-term outcomes; see the CDC State Heart Disease and Stroke Prevention Program Evaluation Guide at [www.cdc.gov/dhdsdp/docs/logic\\_model.pdf](http://www.cdc.gov/dhdsdp/docs/logic_model.pdf)). This evaluation was approved by the University of Hawai'i at Mānoa institutional review board.

## Results

Across the 5 FQHCs, the main program goals were to confirm a hypertension diagnosis and control blood pressure among those with diagnosed hypertension. The primary ways programs sought

to achieve blood pressure control were through blood pressure monitoring and lifestyle change programs. We present the themes that emerged from interviews.

## Programmatic inputs and components

### Inputs

Self-measured BPMP programs started at various times. One site started in September 2016 and 3 sites started in October 2016. The remaining site had an existing self-measured BPMP that started before the grant in 2015, and it used grant funds to maximize its community care model with CHWs. In addition to hiring support staff at all 5 centers, grant funds were used for additional program supplies (eg, log books). Interviewees said staff, existing program curricula related to blood pressure management, and patient-centered practices were important program inputs. All 5 FQHCs engaged CHWs or health educators in self-measured BPMPs, together with pharmacists, nurses, care coordinators, patient navigators, medical assistants, social workers, and/or nutritionists. The American Heart Association donated monitors, which facilitated the creation of a monitor loan program for patients who could not afford to purchase them, and provided educational materials. Other existing patient educational materials used by FQHCs included resources from HDOH, a culturally tailored intervention called *Ola Hou* (hula for hypertension), and the National Diabetes Prevention Program (NDPP). Patient-centered practices, like working with patients to develop individual goals for controlling blood pressure, were important. One provider said, "Shared decision-making is, I think, progressively getting more incorporated into the management of the team as well as the providers."

### Program eligibility

All FQHCs enrolled current patients with hypertension, although 3 sites also used their self-measured BPMPs to formally diagnose hypertension. FQHCs mainly used a systolic/diastolic threshold of 140/90 mm Hg to determine eligibility, and 1 center also used 150/90 mm Hg for its patients who were older than 60.

### Participant recruitment

All FQHCs developed workflows for recruitment, which included internal bidirectional referral systems and electronic health record (EHR) algorithms to identify patients with undiagnosed hypertension. Participants were also recruited via existing programs at FQHCs, such as NDPP classes (Table 1). One site recruited participants through community wellness fairs and screening events; nonpatients were asked to become patients at the FQHC, at which time primary care providers (PCPs) formally referred these patients to the self-measured BPMP. PCPs at other FQHCs also made referrals directly to self-measured BPMP staff; however,

some program staff mentioned having to remind PCPs through meetings or other means that self-measured BPMP was an available resource.

### **Program intake and delivery**

FQHCs used many of the same intake and enrollment procedures. Potential participants complete readiness assessments and program introductions with their PCP or self-measured BPMP staff assigned through the EHR. The level of patient assessment differed by site. One site asked permission of potential patients to schedule a time to explain the process. Another site conducted 3 different patient assessments because many of their clients had other underlying psychosocial issues, such as houselessness or mental illness: “We’ve had times . . . where [the patients] come in, and then they don’t really know what they’re here for. Then they don’t want to do it.” After assessment, patients who were willing and able to participate were formally enrolled in the program.

At 4 FQHCs, patients signed a rental agreement for a loaner blood pressure monitor. A fifth FQHC provided reduced-price, Bluetooth-enabled monitors for purchase, so data could be transferred from the monitor directly into the clinic’s health information system. This clinic’s advanced practice registered nurse said, “We talk with the patient about the cost of the monitor being \$35 and that it’s theirs. They can use it as much as they want, even that they could have 2 people use it in their household.” Enrollment and setup sites included both the FQHC and patient homes. Clinics encouraged participants to take their blood pressure twice per day, although some patients only measured once per day. For sites with loaned monitors, self-measured BPMPs were conducted for 3 to 6 months; the FQHC that sold monitors had no end date for its program. Staff at all sites trained patients on the use and proper placement of the monitor cuff, proper posture during a blood pressure reading, and how to record the reading. Patients often logged their blood pressure readings by hand, and these data were then collected by staff either in the office or at participants’ homes. Self-measured BPMP staff manually calculated average blood pressure and then entered the data into the EHR. Bluetooth-enabled monitors used at 1 site allowed all blood pressure readings of patients to be digitally stored and electronically collected by the site’s staff. PCPs and self-measured BPMP staff used the data to confirm hypertension or titrate medication as appropriate.

### **Hypertension education and lifestyle change**

All 5 FQHCs included additional blood pressure education or lifestyle change components as part of their self-measured BPMPs. All sites provided diet-related education, including menu planning, food preparation demonstrations, referrals to nutritionists, or dietary information. Goal setting and motivational interviewing were

also used by FQHCs to address barriers to lifestyle change and blood pressure monitoring. One site used its behavioral health team to address issues that affect patients’ weight and hypertension:

“We will utilize [behavioral health specialists] to meet with patients to discuss goals of wanting to lose some weight and some motivational cognitive behavioral therapy . . . to help with some patients with multiple chronic diseases. These patients sometimes also have some behavioral health issues that we need to address as well.”

Sites also reported adding in physical activity supports, including hula classes, group bicycle rides, and using on-site gyms or wellness programs. Some sites took advantage of existing on-site programs including NDPP classes, *Ola Hou*, tobacco cessation, or referrals to dietitians.

### **Barriers and facilitators to implementing self-measured BPMPs**

Various barriers to implementing self-measured BPMPs and how sites overcame them were discussed (Table 2). Technologic limitations and availability of monitors were partially overcome by use of donated monitors from the local chapter of the American Heart Association. Patient-related barriers, especially houselessness or mental illness, potentially limited participation in programs; some clinics lost contact with these participants. One staff member said, “At the beginning, we were giving out the monitors at the first appointment. That caused us to lose a lot of monitors, because people wouldn’t come back.” Sites initiated readiness assessments and rental agreements to help with these issues.

Program reach was stymied by a lack of provider referrals because of competing demands. One staff member said, “I hear it from other programs, too, that they don’t get a lot of referrals in general. From what I hear, it’s that [PCPs] have so many other things to do in a visit or whatnot, that this may not be their top priority type of thing.” Staff at 2 different sites mentioned that turnover of PCPs and self-measured BPMPs staff affected capacity, with one saying, “Staff turnover in the recent past has led to backlog of referrals . . . the maximum capacity is 2 patients per day.” One site had started their program using an in-house pharmacist; however, the main funding for that position ended, and program operation was moved to other health education staff. Turnover, although challenging, was partially addressed through presentations of self-measured BPMPs to new PCPs.

In addition to other systemic barriers, interviewees frequently mentioned the lack of an “out-of-the-box” self-measured BPMP curriculum, which led program staff to combine materials from a variety of sources. Systemic facilitators included funding to initi-

ate self-measured BPMPs, technical assistance and shared capacity-building with other implementing sites, and availability of existing educational materials. Another barrier mentioned was the lack of an agreed-upon hypertension diagnosis standard (2,15) among PCPs. One clinic received additional capacity-building assistance on self-measured BPMPs from clinicians who had previously developed a self-measured BPMP (4). Patient word-of-mouth about the program helped spread information about hypertension and encouraged others to participate. Lastly, the patient-centered and team-based care models used by FQHCs and integration of self-measured BPMPs into clinic workflows were important facilitators, which have been effective in other studies (5).

## Implications for Public Health Practice

This process evaluation identified several lessons learned and potential recommendations for policy makers and funding organizations. Foremost, recruitment, scaling, and sustainability were limited by the lack of material supports (eg, monitors) for program implementation, and staff turnover was a major barrier. Funding for other self-measured BPMP positions, like CHWs, is often grant-based, which can lead to burnout and contribute to turnover (16). Four FQHCs limited their program duration because they loaned monitors to patients who could not afford them, while the fifth site performed continuous monitoring, because patients purchased the monitors and because hypertension is a chronic condition. Manual calculation and entry of blood pressure readings into EHRs was a time-consuming process. Data management difficulties hindered further evaluation of the effectiveness of self-measured BPMPs and highlighted the importance of improving the ease and quality of data collection for both patients and providers.

Funding organizations should address the lack of material resources, challenges to remote data collection and monitoring, program reimbursement, and the need for cost-effective health information technology to improve self-measured BPMP uptake and support program sustainability, especially for organizations with populations like those served by FQHCs. In 2018, Hawai'i FQHCs served 157,097 patients, of whom 22,509 had hypertension; of those, 39% had yet to achieve blood pressure control (17), demonstrating the ongoing need for self-measured BPMPs. Second, patients' needs or more urgent health matters interfered with participation in self-measured BPMPs; this was compounded by the lack of an "off-the-shelf" self-measured BPMP curriculum. To address this, sites first assessed patients individually for participation readiness to ensure patients were able to succeed. Second, sites compiled materials from existing programs on dietary and behavior modifications to educate participants on lifestyle changes to manage blood pressure. Then sites provided instrumental supports,

such as opportunities for exercise or leveraging existing lifestyle-change programs. Lastly, FQHCs' team-based care model involved multiple layers of staff to help manage self-measured BPMPs participants and their needs, such as CHWs going to participant homes for monitor setup and data gathering. We were unable to assess whether these social supports or patients' own motivation were contributors to self-measured BPMP enrollment. We were also not able to assess whether differences in manual or Bluetooth-connected monitors, the primary instrumental support provided in these programs, affected compliance and program adherence by participants. Future research should examine these factors. Funders and policy makers should convene sites to provide input on their self-measured BPMP implementation experiences to help develop an off-the-shelf program based on lessons learned.

Five Hawai'i-based FQHCs implemented self-measured BPMPs that strategically addressed patients' psychosocial and health needs. Systemic barriers hindered the sustainability of self-measured BPMPs at some sites and access to data, which hindered an outcome evaluation of these efforts. Policy makers should consider developing off-the-shelf self-measured BPMPs and provide material support to implementation sites through blood pressure monitor reimbursement and further financial support to maintain clinic staff.

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## Author Information

Corresponding Author: David A. Stuppelbeen, PhD, Office of Public Health Studies, University of Hawai'i at Mānoa, 1960 East-West Road, Biomed D-210, Honolulu, HI 96822. Telephone: 808-956-5505. Email: dstupp@hawaii.edu.

Author Affiliations: <sup>1</sup>Healthy Hawai'i Initiative Evaluation Team, Office of Public Health Studies, University of Hawai'i at Mānoa, Honolulu, Hawaii. <sup>2</sup>Chronic Disease Prevention and Health Promotion Division, Hawai'i State Department of Health, Kapolei,

Hawaii. <sup>3</sup>Hawai'i Primary Care Association, Honolulu, Hawaii.  
<sup>4</sup>Lāna'i Community Health Center, Lāna'i City, Hawaii.

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Tables

**Table 1. Workflow of Self-Measured Blood Pressure Monitoring Programs at 5 Hawai'i Community Health Centers**

Health Center Number/ Location/Size <sup>a</sup>	Interviewees	% of Patients With Hypertension (2018) <sup>a</sup>	Activities		
			Recruitment	Intake, Program Delivery, and Follow-Up	Hypertension Education and Lifestyle Change
1. Rural/large	2 CHWs	27.8	<ul style="list-style-type: none"> <li>Recruitment: DPP, EHR</li> <li>Referral: physician</li> <li>Outreach: community, FQHC physicians</li> </ul>	<ul style="list-style-type: none"> <li>Intake: readiness assessment and introduction</li> <li>Enrollment location: office or home</li> <li>Measurement training: office or in home</li> <li>Monitor set-up: in home</li> <li>Program length: target, 3–6 months</li> <li>Log collection: office or home</li> <li>Calculation: manual, entered into EHR for physician</li> </ul>	<ul style="list-style-type: none"> <li>Counseling and goal setting</li> <li>Physical activity: planning, off-site group activities (eg, hula, bicycle rides)</li> <li>Diet: healthy eating</li> <li>Referrals: DPP, care management</li> </ul>
2. Urban/large	Program coordinator	16.0	<ul style="list-style-type: none"> <li>Recruitment: DPP</li> <li>Referral: physician</li> </ul>	<ul style="list-style-type: none"> <li>Intake: readiness assessment, introduction, hypertension education before enrollment (3 sessions)</li> <li>Enrollment location: office</li> <li>Measurement training: office</li> <li>Monitor set-up: office</li> <li>Program length: target, 5 months</li> <li>Log collection: office</li> <li>Calculation: manual</li> </ul>	<ul style="list-style-type: none"> <li>Physical activity: planning, on-site trainer/gym</li> <li>Diet: DASH<sup>b</sup> education</li> <li>Referrals: dietician, tobacco cessation</li> </ul>
3. Rural/large	Pharmacist, 2 CHWs	25.7	<ul style="list-style-type: none"> <li>Recruitment: EHR</li> <li>Referral: physician</li> </ul>	<ul style="list-style-type: none"> <li>Intake: readiness assessment and introduction</li> <li>Enrollment location: pharmacy</li> <li>Measurement training: office</li> <li>Monitor set-up: office</li> <li>Program length: 3 months</li> <li>Log collection: office once per month</li> <li>Calculation: manual, entered into EHR for physician</li> </ul>	<ul style="list-style-type: none"> <li>Physical activity: planning, on-site gym</li> <li>Diet: nutritionist/dietitian referral</li> <li>Incentive program: diet/physical activity-related incentives</li> <li>Referrals: tobacco use cessation, sleep studies</li> </ul>
4. Rural/small	APRN, physician	20.9	<ul style="list-style-type: none"> <li>Recruitment: EHR</li> <li>Referral: physician</li> </ul>	<ul style="list-style-type: none"> <li>Intake: readiness assessment and introduction</li> <li>Enrollment location: office or home</li> <li>Measurement training: office or home</li> <li>Monitor set-up: office or home</li> <li>Program length: unlimited</li> <li>Log collection: at home or in office, transferred by tablet to health information system</li> <li>Calculation: electronic, health information system</li> </ul>	<ul style="list-style-type: none"> <li>Counseling and goal setting</li> <li>Physical activity: planning, on-site wellness program</li> <li>Diet: planning, <i>PLI 'Ohana</i> (existing culturally adapted diabetes curriculum for Native Hawaiians and other Pacific Islanders)</li> </ul>
5. Urban/large	Program coordinator	38.7	<ul style="list-style-type: none"> <li>Recruitment: EHR</li> <li>Referral: physician</li> <li>Outreach: patients and FQHC physicians</li> </ul>	<ul style="list-style-type: none"> <li>Intake: readiness assessment and introduction</li> <li>Enrollment location: office</li> <li>Measurement training: office or home</li> <li>Monitor set-up: office or home</li> <li>Program length: 3 months</li> <li>Log collection: at home or in office</li> <li>Calculation: manual, entered into EHR for physician</li> </ul>	<ul style="list-style-type: none"> <li>Physical activity: on-site group activities (eg, hula)</li> <li>Diet: food demonstrations</li> <li><i>Ola Hou</i> lessons (culturally adapted existing self-measured blood pressure monitoring program curriculum)</li> <li>Referrals: medication payment assistance</li> </ul>

Abbreviations: APRN, advanced practice registered nurse; CHW, community health worker; DASH, Dietary Approaches to Stop Hypertension; DPP, National Diabetes Prevention Program classes; EHR, electronic health record; FQHC, federally qualified health center.

<sup>a</sup> A small health center had <10,000 clients on average during 2016–2018; large centers had ≥10,000 on average for the same period. Source: US Department of Health and Human Services, Health Resources and Services Administration (13).

<sup>b</sup> Source: National Heart, Lung, and Blood Institute (14).

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**Table 2. Barriers and Facilitators to Implementing Self-Measured Blood Pressure Monitoring Programs (BPMPs) at 5 Hawai'i-based Federally Qualified Health Centers**

Category	Action
<b>Barrier</b>	
<b>Availability and limitations of blood pressure monitors</b>	
<ul style="list-style-type: none"> <li>Monitors costly for patients, clinics</li> <li>Older monitors not Bluetooth-enabled, led to hand calculating blood pressure averages, which was time consuming</li> </ul>	Used donated monitors, create monitor loan program for patients
<b>Patient-related issues</b>	
Disabilities, family, finances, houselessness, immigration status, fear of hypertension or worsening of condition, and transportation	<ul style="list-style-type: none"> <li>Staff implemented readiness assessments to identify patients willing and able to participate</li> <li>Some sites implemented pre-enrollment education before distribution of monitors</li> <li>Institute monitor loan agreements</li> <li>Assist patients in their homes</li> </ul>
<b>Staffing challenges</b>	
Provider turnover and other patient needs led to a lack of referrals	Self-monitored BPMP staff had to train refresh physicians to remind them of the service
<b>Systemic challenges</b>	
<ul style="list-style-type: none"> <li>No single “out-of-the-box” self-measured BPMP program available</li> <li>Lack of integrated data management between monitors and electronic health records</li> <li>Uniform data system reporting</li> <li>Disagreement about hypertension diagnostic cutoffs led to delayed referrals at one center</li> <li>Funding and reimbursement for program sustainability</li> </ul>	<ul style="list-style-type: none"> <li>Staff constructed programs from existing materials, recommendations</li> <li>One site used Bluetooth-enabled monitors to transfer data to electronic health record</li> </ul>
<b>Facilitator</b>	
<b>Systemic</b>	
Grant funding	Allowed sites to hire staff for self-measured BPMPs, access technical assistance to build programs
Shared technical assistance	Sites helped each other and shared tips and ideas
Existing resources	American Heart Association resources, other educational programs materials, capacity-building assistance
<b>Patient-related</b>	
Program word-of-mouth	Patients let others know about the program and availability of blood pressure monitors
Hypertension education	Patients helped diffuse information about hypertension to families/friends
<b>Clinical practice-related</b>	
Patient-centered/team-based approaches	Clinics used a variety of staff, including clinicians, pharmacists, and CHWs, who employed patient-centered approaches (eg, lifestyle change, home visits)
Integrating self-measured BPMPs into clinic practice	Integration of self-measured BPMPs into clinical workflows, including into the electronic medical record for referral and entering blood pressure readings

Abbreviations: CHWs, community health workers; BPMPs, blood-pressure monitoring programs.

### PROGRAM EVALUATION BRIEF

# CDC's Sodium Reduction in Communities Program: Evaluating Differential Effects in Food Service Settings, 2013–2016

Julia Jordan, MPH<sup>1,2</sup>; Hadley Hickner, MS, RDN<sup>2</sup>; John Whitehill, MPH<sup>2</sup>; Benjamin Yarnoff, PhD<sup>3</sup>

Accessible Version: [www.cdc.gov/pcd/issues/2020/19\\_0446.htm](http://www.cdc.gov/pcd/issues/2020/19_0446.htm)

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#### PEER REVIEWED

#### Summary

##### What is already known on this topic?

Most people in the United States exceed the recommended daily sodium intake from the sodium already in processed and restaurant foods, whether or not they pick up a saltshaker.

##### What is added by this report?

From 2013 through 2016, CDC's Sodium Reduction in Communities Program demonstrated the extent to which the program's strategies had successfully increased access, availability, and purchases of reduced sodium foods. The program also demonstrated the differential effects of sodium reduction strategies in food service settings.

##### What are the implications for public health practice?

Tailored approaches that are based on a community's available resources, stage of readiness, and food service staff's level of engagement can address some of a strategy's differential effects in food service settings.

## Abstract

High sodium intake can lead to hypertension and increase the risk for heart disease and stroke; however, research is lacking on the effectiveness of community-based sodium reduction programs. From 2013 through 2016, the Centers for Disease Control and Prevention (CDC) funded 10 state and local health departments to implement sodium reduction strategies across diverse institutional food settings. Strategies of the Sodium Reduction in Communities Program (SRCP) are implementing food service guidelines, making menu modifications, enabling purchase of reduced-sodium foods, and providing consumer information. CDC aggregated

awardee-reported performance measures to evaluate progress in increasing the access, availability, and purchase of reduced sodium foods. Evaluation results of the SRCP show the potential differential effects of sodium reduction strategies in a community setting and support the need for additional community-level efforts in this emerging area of public health.

## Introduction

Excessive sodium intake is associated with increased risk of high blood pressure, coronary heart disease, and stroke (1–3). Nearly 85% of US adults and children currently exceed the 2015 to 2020 Dietary Guidelines for Americans recommended limit of 2,300 mg of sodium per day (4). Although about half of US adults report reducing the amount of salt they add to food, most dietary sodium comes from commercially processed and restaurant foods (5). Inadequate access to low-sodium foods makes it difficult for people to lower their sodium intake; therefore, sodium reduction strategies must extend beyond individual-level behavior change.

In 2010, the Institute of Medicine released their report, *Strategies to Reduce Sodium Intake in the United States*, which recommended government action to reduce sodium in the US food supply (6). The Centers for Disease Control and Prevention (CDC) responded by launching a population-level pilot program aimed at reducing the sodium content of foods served, sold, and procured across a variety of institutional settings in the United States. The first round of the Sodium Reduction in Communities Program (SRCP), from 2010 through 2013, funded state and local health departments to implement sodium reduction strategies in various settings. Strategies included implementing policies that supported sodium reduction efforts, advertising low-sodium foods to promote heart health, and adopting procurement policies to enhance sodium reduction efforts. Evaluations of the demonstration project of CDC and its awardees indicated that these strategies were a promising approach to sodium reduction, but evaluations also in-



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icated a need for flexibility in tailoring activities to address context-specific differences among implementation sites, such as restaurants, hospitals, and schools (7–12).

## Purpose and Objectives

Recognizing the importance of incorporating evaluation findings, CDC implemented an adapted version of SRCP for the 2013 to 2016 program that included lessons learned from the initial pilot program. To build the foundation of evidence for these strategies, CDC evaluated SRCP by measuring changes in the average sodium content of foods, access to and purchase of low-sodium foods, and population intake of sodium in the pilot and in the 2013 to 2016 version. CDC conducted a comprehensive evaluation to explore the influence of SRCP strategies and associated activities on food service partners, menus, sales, and patrons of food service settings to fill a gap in the literature and to inform future work in this emerging area. Each individual SRCP awardee also conducted an internal evaluation. CDC aggregated the outcome data from the awardee evaluations to assess the effect of sodium reduction strategies in 4 domains: food service guidelines and nutrition standards, meal and menu modifications, strategies that influence the purchase of foods, and complementary consumer information activities.

## Intervention Approach

CDC funded 7 SRCP awardees in state and local health departments in 2013 and 3 additional awardees in 2014 to work on improving community support for sodium reduction and to build practice-based evidence around effective community strategies to reduce sodium consumption. Awardees represented diverse communities across the country, including states, counties, and cities from each region.

The program design consisted of 4 strategies to achieve the long-term goal of improving prevention and control of hypertension by increasing access to and availability of reduced sodium foods in the community to reduce sodium intake. Strategies included 1) developing and implementing food service guidelines and nutrition standards, 2) implementing menu or meal modifications, 3) implementing strategies that may enhance the selection and purchase of sodium-reduced foods, and 4) offering complementary venue-specific consumer information. Awardees recruited and provided technical assistance to food service partners to plan and implement activities that supported the 4 strategies. Strategies were implemented in partnering hospitals (staff and visitors), worksites (employees), independent restaurants (patrons), and congregate

and distributive meal programs (ie, senior meals, early childhood education centers, prisons) for a total of 20 food service settings across all awardees. Strategies were tailored in each setting, based on goals and capacity of the partner. Awardees developed activities in collaboration with food service partners (Box).

### Box. Strategies and Activities in the Sodium Reduction in Communities Program, 2013–2016

#### Strategy 1. Develop and Implement Food Service Guidelines and Nutrition Standards

Adopt existing nutrition standards for foods sold at food service settings (eg, US General Services Administration and Health and Human Services Sustainability Guidelines).

Develop and implement policies that set nutrition standards (eg, city or county policies for foods served in government buildings).

Develop language and implement procurement policies into vendor contracts.

Include limits for sodium in product specifications on food orders with distributors and manufacturers.

Develop healthy restaurant incentive programs and engage entities to participate.

#### Strategy 2. Implement Menu and Recipe Modifications to Reduce Sodium

Strategically plan menu cycles.

Decrease or eliminate added salt or salt-containing ingredients in a recipe.

Replace an ingredient with a low-sodium alternative in a recipe.

Modify portion sizes.

Implement standardization of recipes to measure accurate sodium content.

Eliminate the use of “free salting” (adding additional salt to recipes for flavor).

Train food service staff on culinary techniques.

#### Strategy 3. Implement Strategies to Enhance Selection or Purchase of Low-sodium Foods

Provide point of purchase nutrition information or labeling system.

Make changes to the built environment where foods are served (such as strategic placement of healthier foods).

Competitively price healthier options.

Offer taste tests or samples.

Promote low-sodium options through other initiatives (such as fresh produce as part of a culinary garden).

#### Strategy 4. Offer Complementary Venue-Specific Consumer Information Activities

Promote changes and distribute promotion materials (such as menu options, logos, table tents, menu inserts).

Train cafeteria and café operators on behavioral economics.

Collect and analyze customer satisfaction and apply feedback.

## Evaluation Methods

CDC contracted with RTI International to develop and implement a 3-year quantitative evaluation for SRCP that was based on the CDC Evaluation Framework (13). The RTI International Institutional Review Board reviewed this evaluation and determined that it is not human subject research. CDC aimed to use the evaluation to build an evidence base for community-based sodium reduction efforts by answering the overarching evaluation question, “To what extent is it possible to implement strategies in community settings to reduce the amount of sodium in foods?”

Data for our evaluation came from performance measure data, a component of awardees’ local evaluations. Awardees annually reported results of their local evaluations to CDC, including their performance measure data. On the basis of standard guidance provided by CDC, awardees selected and reported measures from a menu of options, allowing flexibility in their local evaluations according to the food service setting in which they worked, the specific activities they implemented, data availability, and interests of stakeholders. Each awardee was required to select at least 1 performance measure related to each strategy: increased availability of low-sodium foods, increased accessibility of sodium-reduced foods, increased selection and purchase of low-sodium foods, and decreased sodium intake. In this evaluation, 4 measures of program effects were examined across the strategies implemented and were most widely reported by awardees:

- Average sodium content of targeted foods or meals (n = 12)
- Number of food service organizations offering new low-sodium foods (n = 20)
- Sales of low-sodium food options (n = 5)
- Number of people purchasing or selecting low-sodium food items (n = 11)

To report performance measures, awardees developed or modified existing tools to collect baseline data at the start of the program and annually thereafter. One example of a commonly used tool is the Sodium Practices Assessment Tool, developed by one awardee and modified by others to fit their specific environment. This tool used environmental scans, pantry observations, and food service self-assessments to understand if and how sodium reduction strategies were being implemented (14). CDC aggregated data across all reporting awardees and computed the mean difference of each outcome measure at baseline and at the end of the program (3 years for 7 awardees and 2 years for 3 awardees). To evaluate the change in average sodium content, the baseline average content was subtracted from the final follow-up average content for each awardee and averaged across awardees that collected the measure. To evaluate the change in number of entities offering low-sodium

foods, the total purchased low-sodium options, and the number of purchasing or selecting low-sodium foods, CDC subtracted the baseline estimate for each outcome measure from the estimate at final follow-up and summed across all awardees.

## Results

The average sodium content of targeted foods or meals decreased by 261 mg from 946 mg at baseline, to 685 mg at final follow-up in the 12 food service settings that submitted data. The reduction was largest in congregate meal programs (386 mg), followed by hospitals (223 mg) and worksites (44 mg) (Table).

SRCP activities led to an increase in the number of people with access to environments with healthy food options, including low-sodium foods. These people frequented settings where low-sodium foods were available. Across all 20 food service settings of various types, the number of organizations offering new low-sodium foods increased to an estimated 455 from a baseline of 0 organizations. The increase was largest among restaurants (244), followed by congregate meals (91), worksites (81), and hospitals (39). Combined, these organizations reached an estimated 2,029,408 people. Hospitals reached the largest number of people (1,513,755 visitors and employees), followed by worksites (366,800 employees), congregate meal programs (137,435 patrons), and restaurants (11,417 patrons).

SRCP activities also increased the sales of low-sodium foods. From baseline, low-sodium food items purchased by patrons in the 5 food service settings that reported this measure increased by 250,701 (from 62,793 items at baseline to 313,494 items at final follow-up). Most of this increase was from worksites (248,542 items).

SRCP also influenced the number of people who reduced their sodium intake through the purchase of low-sodium foods. Across 11 food service settings, an estimated 140,596 people purchased low-sodium food items compared with baseline (from 18,107 people at baseline to 158,704 people at final follow-up). The outcome was greatest in worksites (71,314 people), followed by congregate meals (39,908 people), restaurants (28,807 people), and hospitals (568 people).

## Implications for Public Health

As one of the first cross-site outcome evaluations of a community-level sodium reduction program, this evaluation’s outcomes help to build evidence for the strategies implemented. Results show that SRCP strategies increased the availability of low-sodium options by decreasing the sodium content of targeted food items, and patrons chose to purchase low-sodium items when they were

available, especially in worksites. Results also suggest that when organizations implement SRCP strategies, more people have access to low-sodium foods, and the sales of low-sodium foods increase.

In addition to demonstrating the overall effects of these interventions, results also offer insight into the differential effects of food service settings that can help inform future program design. Results demonstrated the greatest potential for reach might be in hospitals (39 hospital partners reached 1,513,755 people), probably because of the large number of visitors and employees that eat in hospital cafeterias. Hospitals have an opportunity to consistently provide low-sodium food options to employees and to expose visitors to these options on a less frequent basis. Also, although 2 SRCP awardees partnered with 244 restaurants, the restaurants reached only 11,417 people, and the reach was less consistent than with other venues. Results suggest that sodium reduction efforts in worksites (71,314 people) and congregate meal settings (39,908 people) had the greatest effect on reducing sodium intake because the population remains consistent over time. Program planners should consider the tradeoff between increased reach and the consistency of that reach when identifying potential food service settings for collaboration.

The evaluation of SRCP demonstrates the potential influence of sodium reduction strategies to increase the access, availability, and purchase of low-sodium foods in a community setting and supports the need for additional community work in this emerging prevention effort. These results are essential to catalyze further action to increase low-sodium food choices and improve consumer nutrition. By partnering with commercial food service settings, SRCP targets one of the largest sources of sodium in the US food supply and addresses a major risk factor for high blood pressure.

Our study had limitations. Because the overall evaluation of SRCP relied on performance measures reported by awardees and because not all awardees were required to report the same performance measures, our evaluation was limited by incomplete data. Awardees also self-reported their data, which may have led to reporting bias, although CDC provided awardees with standard measure definitions and guidance on appropriate data sources to limit this bias. At baseline, an assessment was not completed around the extent of low-sodium offerings in partnering organizations, but all partner organizations increased low-sodium options during the program. Therefore, the measure of entities offering low-sodium foods only measures progress as a result of SRCP implementation. Additionally, SRCP could not measure sodium intake; therefore, the number of people purchasing low-sodium food items was used as a proxy. However, using this proxy limited our ability to identify duplicate counts if a patron made multiple purchases at an intervention site. A third iteration of the SRCP is be-

ing developed using lessons learned from this evaluation. The funding cycle has been increased to 5 years to provide additional time for implementation and evaluation. The evaluation will standardize performance measure reporting to strengthen the evidence of distinct sodium reduction strategies.

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## Author Information

Corresponding Author: Julia Jordan, MPH, Centers for Disease Control and Prevention, Division for Heart Disease and Stroke Prevention, 4770 Buford Hwy Mailstop S107-3, Atlanta, GA 30341. Telephone: 770-488-4818. Email: kog7@cdc.gov.

Author Affiliations: <sup>1</sup>IHRC, Inc, Atlanta, Georgia. <sup>2</sup>Centers for Disease Control and Prevention, Division for Heart Disease and Stroke Prevention, Atlanta, Georgia. <sup>3</sup>RTI International, Public Health Economics Program, Research Triangle Park, North Carolina.

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Table

Table. Estimated Effects of Sodium Reduction Program in Food Service Venues, Overall and by Setting, 2013–2016

Setting	No. of Awardee Settings	Baseline Intake	Final Follow-up	Change from Baseline to Follow-up
<b>Average sodium content of targeted foods or meals (mg)</b>				
Overall	12	946	685	-261
Congregate	5	1,484	1,098	-386
Hospitals	5	670	447	-23
Restaurants	0	NA	NA	NA
Worksites	2	287	243	-44
<b>Settings offering new low-sodium foods</b>				
Overall	20	0	455	+455
Congregate	6	0	91	+91
Hospitals	6	0	39	+39
Restaurants	2	0	244	+244
Worksites	6	0	81	+81
<b>Low-sodium food items sold</b>				
Overall	5	62,793	313,494	+250,701
Congregate	1	795	1,684	+889
Hospitals	2	1,353	2,623	+1,270
Restaurants	0	NA	NA	NA
Worksites	2	60,645	309,187	+248,542
<b>Number of people purchasing or selecting low-sodium foods</b>				
Overall	11	18,107	158,704	+140,597
Congregate	3	1,935	41,843	+39,908
Hospitals	1	97	665	+568
Restaurants	2	16,000	44,807	+28,807
Worksites	5	75	71,389	+71,314

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## ORIGINAL RESEARCH

# The Arkansas Minority Barber and Beauty Shop Health Initiative: Meeting People Where They Are

Chimfumnanya Smith, MPH, CHES<sup>1</sup>; Austin Porter III, DrPH, MPH<sup>1,2</sup>; Joyce Biddle, MPA, MPH<sup>1</sup>;  
Appathurai Balamurugan, MD, DrPH<sup>1,2</sup>; Michelle R. Smith, PhD, MPH<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

Chronic diseases disproportionately affect racial/ethnic minority communities. Barber and beauty shops are recognized as viable locations to promote health and screen for chronic diseases.

**What is added by this report?**

This report describes screening for chronic health conditions at a barber and beauty shop–based screening program, the effect of a health education promotion campaign, and how medical referrals and participant follow-up can be integrated into screening initiatives that are based in barber and beauty shops.

**What are the implications for public health practice?**

Public health programs that seek to target racial/ethnic minority populations should meet people where they are in the community. Community-based health education and behavior modification are effective ways to decrease rates of chronic conditions among racial/ethnic minority populations.

## Abstract

**Introduction**

The Office of Health Equity at the Arkansas Department of Health created the Arkansas Minority Barber & Beauty Shop Health Initiative (ARBBS) to address cardiovascular disease (CVD) among racial/ethnic minority populations. The objective of this study was to describe CVD-related screening results for ARBBS participants and their knowledge of CVD-related risk factors, signs, and symptoms before and immediately after participation in a screening event.

**Methods**

ARBBS screening events were held from February 2016 through June 2019 at barber and beauty shops in 14 counties in Arkansas. During each event, participants were screened for hypertension, high cholesterol, and diabetes; surveys on CVD-related knowledge were administered before (pretest) and after (posttest) screening. Onsite public health practitioners reviewed surveys and identified abnormal screening results. Participants with abnormal screening results were counseled and given a referral to follow up with a primary care physician, wellness center, or charitable clinic. The nurse coordinator followed up to confirm that a visit or appointment had been made and provide case-management services.

**Results**

During the study period, 1,833 people were screened. The nurse coordinator followed up with 320 (55.7%) of 574 unique referrals. Of the 574 referrals, 418 (72.8%) were for hypertension, 156 (27.2%) for high cholesterol, and 120 (20.9%) for diabetes. The overall knowledge of risk factors and symptoms of heart attack and stroke increased significantly by 15.4 percentage points from pretest to posttest (from 76.9% to 92.3%;  $P < .001$ ). The follow-up approach provided anecdotal information indicating that several participants discovered they had underlying medical conditions and were given medical or surgical interventions.

**Conclusion**

Through referrals and follow-ups, ARBBS participants gained greater knowledge of chronic disease prevention and risk factors. Additionally, this program screened for and identified people at risk for CVD.

## Introduction

Cardiovascular disease (CVD), the leading cause of mortality globally, represented 31.0% of all global deaths in 2017 (1). Of 17.9 million deaths worldwide from CVD in 2017, 85.0% were attributed to myocardial infarctions and stroke (2). In the United States, heart disease and stroke are the first and fifth leading



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causes of death, respectively (3). In 2018, 1 in every 4 deaths was associated with heart disease, and 1 in 20 deaths was associated with stroke (4).

In the United States, disparities in CVD outcomes are exacerbated by the social constructs and inequalities that disproportionately affect racial/ethnic minority populations (5). Compared with other racial/ethnic populations, Black people have the highest risk for both heart disease and stroke (5). Black people develop CVD risk factors (eg, hypertension, obesity, diabetes) at an earlier age and have a higher CVD morbidity and mortality rate compared with their White counterparts (6,7). Despite the underreporting of data among Hispanic people, heart disease accounts for 20.1% of their deaths, which is comparable to rates among Black people, at 23.7% (6).

Black people have more than twice the incidence of stroke and are twice as likely to die of a stroke compared with their White counterparts (4,8). In the United States, stroke is the third leading cause of death among Black people, fourth among Hispanic people, and fifth among White people (6). Hispanic people are more likely than non-Hispanic White people to be unaware of their risks for CVD (9).

The trends in heart disease and stroke in Arkansas are similar to national trends: they are the first and fifth causes of death, respectively (10). Of the 50 states, Arkansas ranks third highest in heart disease deaths and seventh in stroke deaths (10). The state faces significant challenges: 35.0% of adults are obese, 32.5% are physically inactive, and 22.3% are tobacco users (11). According to the US Census Bureau, Arkansas had a population of 3,017,804 people in 2019, with White people representing 79.0% of the population, Black people representing 15.7%, and other races representing the remaining 5.3% (12). Race/ethnicity plays an important role in the prevalence of CVD in the state; Black and Hispanic people have higher rates than White people of heart disease and stroke (10,13). Also, the prevalence of hypertension is higher among Black people (46.0%) than among White people (39.0%) (14). The Arkansas Red County Life Expectancy Profile shows that Black people have a lower life expectancy than their White counterparts: 68.6 years for Black men, compared with 71.1 years for White men, and 75.8 years for Black women, compared with 76.0 years for White women (15).

Barbershops and beauty shops have historically served as places where people not only get hair services but also can openly and honestly talk about issues of importance in their community (16,17). Barbershops and beauty shops are conveniently located and are frequently visited by community patrons of all ages; these locations are important and culturally appropriate avenues for addressing health and social issues (16). Health promotion programs

that target Black people, particularly Black men, have partnered with barbershop owners who are trusted members of their communities to help deliver health messages and help address health issues that disproportionately affect Black communities (18). Studies have described these partnerships, demonstrated an increase in knowledge and positive changes in health behaviors among clients, and emphasized the need for community health education-based programs to increase their outreach efforts to at-risk populations through barber and beauty shop health intervention initiatives (16,18,19).

In 2013, the Office of Health Equity, formerly known as the Office of Minority Health & Health Disparities, at the Arkansas Department of Health, created the Arkansas Minority Barber & Beauty Shop Health Initiative (ARBBS) to address CVD and its risk factors among racial/ethnic minority populations. The mission of the initiative was to increase public awareness about heart disease and stroke and empower racial/ethnic minority communities to better understand hypertension prevention and management. This initiative differed from other barbershop health promotion programs in that, in addition to outreach at barbershops, it included beauty shops and barber/beauty colleges and added a program component for the Hispanic population. The initiative also included follow-up on participants who had abnormal screening results. These participants were referred to their family physician or a charitable clinic for treatment. The primary objective of this study was to describe CVD-related screening results of ARBBS participants and knowledge of CVD-related risk factors, signs, and symptoms before and immediately after participation in a screening event.

## Methods

In March 2013, the Office of Health Equity, in partnership with the cosmetology section of the Arkansas Department of Health, contacted minority-owned barbershops, beauty shops, and barber/beauty colleges and invited them to an educational session where CVD risk factors (eg, hypertension, diabetes, obesity, tobacco use) and their effect on racial/ethnic minority communities were discussed. The ARBBS initiative was introduced to the business owners, and they were asked if they would want their shops or colleges to be screening locations. To qualify as a screening site, a business was required to meet a threshold of at least 50 clients on a given Saturday, 5 to 10 barbers or beauticians working on a given Saturday, and the capacity to host 18 to 36 volunteer team members without disrupting their flow of business. All locations that met the criteria and whose owners were willing to participate signed a form approving their businesses to serve as health screening locations. This study was approved by the institutional review

board at the University of Arkansas for Medical Sciences. The study was conducted in 14 counties from February 2016 through June 2019 (the study period).

### Volunteer recruitment and training

Medical and nonmedical volunteers were recruited from local universities and colleges, the health department, local hospitals, and nonprofit organizations in the community. Volunteers recruited included physicians, advanced nurse practitioners, registered nurses, dietitians/nutritionists, certified health education specialists, public health practitioners, nursing students, pharmacy students, medical students, public health students, Spanish interpreters, and laypeople. Recruitment emails were sent out to various listservs, and flyers were printed and distributed to colleges and organizations.

All volunteers were required to attend a mandatory 2-hour standardized training before participating in the health screenings. The training included a review of a participant survey, protocols for each volunteer role, and instructions on how to administer a survey properly. Twenty-one training sessions were conducted during the 4 years, with 1,012 total volunteers in attendance.

### Participant recruitment

Study participants were recruited from the clientele of participating beauty shops and barbershops and via bilingual (English and Spanish) radio, internet, newspaper, and television advertisements. People who agreed to participate in the health screening signed a consent form that detailed the types of screening to be performed as well as their rights to confidentiality and privacy. All participants had to be aged 18 years or older.

### Screening process

The screening consisted of 8 checkpoints: 1) registration, 2) blood pressure measurement (via sphygmomanometer), 3) blood glucose and cholesterol measurement (via finger stick), 4) education on tobacco cessation, 5) education on heart disease and stroke, 6) screening for body mass index (BMI) (height and weight were measured) and education on proper nutrition and physical activity, 7) counseling and medical referrals, and 8) posttest survey. A pretest survey was administered at checkpoints 2 through 5. Volunteers were assigned to checkpoints on the basis of their training and expertise. Health educators and health practitioners conducted the educational components on CVD (heart attack and stroke), CVD risk factors (high blood pressure, high cholesterol, diabetes, and tobacco use), and proper physical activity and nutrition habits. Participants received counseling and medical referrals at checkpoint 7 from volunteers who were either medical doctors

or advanced nurse practitioners. The screening process took approximately 45 minutes to an hour to complete.

Participants who had abnormal screening results for hypertension, diabetes, or cholesterol (Box; [20,21]) were referred to medical providers or charitable clinics for further evaluation and follow-up. Participants who had a primary care physician were referred to seek treatment from their provider. Participants who did not have a primary care physician were referred to charitable clinics or medical providers in their area, regardless of their health insurance status. Participants who had a BMI of 25.0 kg/m<sup>2</sup> or higher were referred to health care providers for support with proper nutrition and physical activity.

#### Box. Chronic Disease Risk Levels

##### Hypertension risk (blood pressure measurements)

Hypotension (90 mm Hg/<60 mm Hg)  
Normal (91–120 mm Hg/61–80 mm Hg)  
Prehypertension (121–139 mm Hg/81–89 mm Hg)  
Medium stage 1 (140–159 mm Hg/90–99 mm Hg)  
High stage 2 (160–179 mm Hg/100–109 mm Hg)  
Critical (≥180 mm Hg/≥110 mm Hg)

##### Cholesterol levels

Hypocholesterolemia (0–49 mg/dL)  
Normal (50–200 mg/dL)  
Borderline (201–239 mg/dL)  
High (≥240 mg/dL)

##### Diabetes risk (blood glucose levels)

Low (0–70 mg/dL)  
Normal (51–140 mg/dL)  
Prediabetes (141–200 mg/dL)  
Diabetes (≥201 mg/dL)

##### Body mass index risk (kg/m<sup>2</sup>)

Underweight (<18.5)  
Normal (18.5–24.9)  
Overweight (25.0–29.9)  
Obese (≥30.0)

**Pretest and posttest.** A pretest questionnaire and posttest questionnaire were used to obtain data on demographic characteristics, access to care, chronic disease risk levels, knowledge of chronic diseases, and medical referral status. Trained volunteers administered a paper-and-pencil bilingual (English and Spanish) survey to each participant during checkpoints 2 through 5 (pretest) and at checkpoint 8 (posttest). Each questionnaire had a unique identification number. Survey questions were adapted from the Centers for

Disease Control and Prevention's Behavioral Risk Factor Surveillance System. The pretest questions asked about demographic characteristics (age, sex, race/ethnicity, education) and whether the participant had a personal physician and health insurance. In addition, both the pretest and posttest survey assessed knowledge of chronic disease with the following multiple-choice questions: "What should a normal blood pressure be?" Responses for "top number" were less than 200, 130, 140, greater than 150, or don't know. Responses for "bottom number" were less than 80, 90, 100, greater than 120, or don't know. "What is a normal total cholesterol level?" Responses were less than 200, 250, 300, 400, or don't know. Two questions were in true-false format: 1) "The following are some symptoms of a stroke" Responses were facial droop, slurred speech, weakness in arm or leg. 2) "The following are some symptoms of a heart attack" Responses were chest pain; nausea/flu-like symptoms; neck, back, and jaw pain; shortness of breath). Finally, "What is the first thing you should do if you thought someone was having a stroke or heart attack?" Responses were "take them to the hospital," "Tell them to call their doctor," "Call 911," "Call their spouse or family member," and "don't know."

### Medical referrals

When a participant was referred for medical follow-up, the study team initiated a new form. This bilingual medical referral form recorded the participant's contact information and screening results and was used to track people who were referred for follow-up medical care. The unique survey number was transferred to the medical referral form if the participant received a referral. The nurse coordinator, a staff member of the Office of Health Equity, conducted follow-up telephone calls within 30 days after the screening and every 3 months thereafter for a year. During the follow-up calls, participants were asked if they kept their medical appointments, started new medications, had a change in medication, changed their dietary habits, started exercising, or quit tobacco use (if applicable); their responses were self-reported. We tracked the number of participants who kept their medical appointments and the number of participants who agreed to return to the health screening the following year. The nurse coordinator also noted any other information that the participants provided, such as whether they had received any surgical interventions as a result of the screening intervention.

### Data analysis

Our analytic sample consisted of 1,833 participants. We used descriptive statistics to summarize data on the demographic characteristics of the participants, their access to care (health insurance and personal physician), knowledge of disease, and screening results. We used data obtained from medical referral and participant

follow-up forms to examine compliance (eg, keeping physician appointments or taking hypertension medication) and management of risk factors (eg, exercise, proper diet to reduce obesity, smoking cessation) among participants who received referrals. We conducted  $\chi^2$  tests to determine whether the education received during the screening event improved the number of correct answers on the posttest. We managed all data obtained from the health screenings and follow-up telephone calls in REDCap version 9.1.20 (Vanderbilt University). We used SAS version 9.4 (SAS Institute Inc) to conduct all analyses.

## Results

Of the 1,833 participants, most (60.9%) were female, Black (62.7%), and had some college (27.3%) or were college graduates (27.5%) (Table 1). Most (54.6%) were younger than 45, most (78.6%) had health insurance, and most (68.7%) had a personal physician.

Most (69.9%) were at risk for hypertension or had hypertension: 35.1% had prehypertension, 22.1% had stage 1 hypertension, 9.4% had stage 2 hypertension, and 3.3% had critical hypertension (Table 2). Most (72.2%) participants had normal cholesterol levels, most (80.2%) had normal glucose levels, and about half (49.2%) had a BMI  $\geq 30.0$ .

Of the 574 unique referrals recorded during the study period, 320 (55.7%) were successfully contacted, with 161 (28.0%) keeping their appointments with their primary care provider. Through these follow-ups, we were made aware of at least 10 instances in which a participant had received surgical interventions because of abnormal screening results. Of the 574 referrals, 418 (72.8%) were for hypertension, 156 (27.2%) for high cholesterol, and 120 (20.9%) for diabetes.

The average percentage of correct answers to the questions on normal blood pressure, normal cholesterol, and what to do first if someone were having a stroke or heart attack increased from 60.8% to 87.6% ( $P < .001$ ) from pretest to posttest (Table 3). Among the multiple-choice questions, the largest improvement was for the question, "What is a normal total cholesterol level?" The percentage increased from 44.6% to 87.9% ( $P < .001$ ).

The average percentage of correct answers to the true-false questions on the symptoms of a stroke and heart attack increased by 8.8 percentage points (from 86.2% to 95.0%;  $P < .001$ ) (Table 3). Among the true-false questions, the largest improvement was in the question on symptoms of a heart attack: 70.4% of participants on the pretest and 90% on the posttest indicated that this was true, an increase of 19.6 percentage points ( $P < .001$ ). The overall

knowledge of risk factors and symptoms of heart attack and stroke increased significantly from pretest to posttest (from 76.9% to 92.3%;  $P < .001$ ).

## Discussion

The results of this study highlight the efforts of a screening program designed to reach a population with a disproportionate share of many chronic diseases. The literature is rich in highlighting innovative ways to reach racial/ethnic minority populations, particularly Black people, to screen for specific chronic diseases (22–24). Many of these screening activities stress the importance of meeting people where they live and work and have been held in churches, barber/beauty shops, community centers, and other non-traditional locations. The ARBBS initiative sought not only to screen for chronic diseases among a high-risk population but also to provide education and refer people who required follow-up care to a health care provider.

The initial referral and nurse coordinator follow-up were unique aspects of this screening program. The program sought to identify and refer participants with abnormal screening results to an appropriate health care provider and to follow up on treatment outcomes. Using a point of contact after the initial abnormal screening results has been shown to be effective in increasing compliance (25). A study by Rorie et al used resident housing advocates (RHAs) to follow up with residents of public housing who had abnormal screening results (25). The RHA offered to help make appointments for residents and accompany residents to their follow-up appointment; the proportion of participants who completed a follow-up appointment increased from 15.0% to 55.0% (25). Although our program attempted to contact all participants with abnormal screening results, we made contact with 55.7%, and 28.0% kept their follow-up appointments within 30 days of the screening event. Nevertheless, we received anecdotal information that at least 10 participants with abnormal screening results subsequently obtained potentially life-saving surgeries.

Barber and beauty shops have been used as avenues to promote health in the Black community (16,26). Many promotion activities were associated with an increase in health knowledge. A study conducted by Luque et al administered a health education intervention in barbershops that aimed to increase the knowledge and awareness of prostate cancer and screening in the African American community (26). These researchers found a significant increase in knowledge among clients given educational materials on prostate cancer (26). Similarly, the results of our study indicated that the knowledge of chronic diseases and risk factors among participants increased significantly after the intervention.

Modifiable risk factors such as high blood pressure, obesity, diabetes, physical inactivity, and tobacco use increase CVD disparities between non-Hispanic White people and Black and Hispanic people (7,27). About 46.8% of Black people and 47.0% of Hispanic people are obese, and both populations are more likely than non-Hispanic White people to be diagnosed with hypertension and diabetes and be physically inactive (8,28). Systematic, environmental, and structural factors also contribute to the high risk and mortality rates of CVD among Black and Hispanic people (29). Racism, poverty, and low socioeconomic status are associated with increased CVD risk and mortality rates among Black people and Hispanic people (5,30). Because of inequities worsened by the social determinants of health among many members of racial/ethnic minority populations, it is essential to provide targeted educational and health-promoting interventions to these populations.

Our initiative had several strengths, including the follow-up of participants with abnormal screening results, the inclusion of Black women and Hispanic populations, and the use of nontraditional locations. In addition, more than half of participants were aged 45 or younger; information obtained by people at these younger ages may help to reduce the risk for chronic diseases later in life. Other health promotion activities, such as screening for HIV and sexually transmitted infections, breast cancer, prostate cancer, and mental health, can easily be incorporated into the structure of our initiative. Programs such as ours can be sustained through in-kind contributions and collaboration with various partner organizations, such as hospitals, universities or colleges, and other local community organizations.

Our study has several limitations. First, we used a convenience sample. Barbershop and beauty shop clientele who self-selected to participate in the program may have been different from those who elected not to participate. Second, we did not measure the long-term effect of knowledge gained during the intervention. We assessed knowledge gained immediately after the intervention. Future studies should be designed to measure the long-term effects of the program on participants' knowledge and changes in health outcomes. Third, we did not conduct regression analyses to identify variables such as health insurance status, ethnicity, and sex that may be associated with keeping follow-up appointments. Fourth, we did not collect data on people lost to follow-up; this information could have provided additional insight into the effect of our intervention. Future research should explore other types of follow-up interventions, such as medication therapy programs for populations with limited access to these programs. Additionally, a cost-benefit analysis of the initiative should be conducted.

Notwithstanding these limitations, the results of our study add to the evidence that barber and beauty shops are viable options for promoting healthy behaviors and conducting screening programs

in racial/ethnic minority communities. To the best of our knowledge, our program was the first to incorporate Black women and Hispanic participants. Participants were screened for chronic health conditions and received education on how to reduce their risk for these conditions. Follow-up on abnormal screening results was a critical element of our program: it sought to ensure that patients were further tested and treated by a medical provider. Screening programs must be intentional in screening, educating, and intervening with populations at risk of chronic diseases. Public health programs that seek to target racial/ethnic minority populations should meet people where they are in the community. Community-based health education and behavior modification can be effective measures to decrease CVD risk factors in racial/ethnic minority populations.

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## Author Information

Corresponding Author: Chimfumnanya Smith, MPH, CHES, Arkansas Department of Health, 4815 West Markham St, Little Rock, AR, 72205. Telephone: 501-661-2282. Email: Chychy.Smith@arkansas.gov.

Author Affiliations: <sup>1</sup>Arkansas Department of Health, Little Rock, Arkansas. <sup>2</sup>Fay W. Boozman College of Public Health, University of Arkansas for Medical Sciences, Little Rock, Arkansas.

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## Tables

**Table 1. Demographic Characteristics of Adults Participating in the Arkansas Minority Barber & Beauty Shop Health Initiative (N = 1,833), Arkansas, 2016–2019**

Characteristic	No. (%)
<b>Age, y</b>	
18–24	284 (15.5)
25–34	371 (20.2)
35–44	346 (18.9)
45–54	270 (14.7)
55–64	312 (17.0)
≥65	212 (11.6)
Unknown/missing	38 (2.1)
<b>Sex</b>	
Male	707 (38.6)
Female	1,116 (60.9)
Unknown/missing	10 (0.5)
<b>Race/ethnicity</b>	
White	305 (16.6)
Black	1,150 (62.7)
Hispanic	311 (17.0)
Other	40 (2.2)
Unknown/missing	27 (1.5)
<b>Education</b>	
<High school graduate	262 (14.3)
High school graduate	478 (26.1)
Some college	501 (27.3)
College graduate	504 (27.5)
Unknown/missing	88 (4.8)
<b>Has health insurance</b>	
Yes	1,440 (78.6)
No	363 (19.8)
Unknown/missing	30 (1.6)
<b>Has a personal physician</b>	
Yes	1,259 (68.7)
No	473 (25.8)
Not sure/refused	2 (0.1)
Unknown/missing	99 (5.4)

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**Table 2. Screening and Referral Results of Adults Participating in the Arkansas Minority Barber & Beauty Shop Health Initiative (N = 1,833), Arkansas, 2016–2019**

Result	No. (%)
<b>Blood pressure</b>	
Hypotension (90 mm Hg/<60 mm Hg)	5 (0.3)
Normal (91–120 mm Hg/61–80 mm Hg)	524 (28.6)
Prehypertension (121–139 mm Hg/81–89 mm Hg)	643 (35.1)
Stage 1 hypertension (140–159 mm Hg/90–99 mm Hg)	405 (22.1)
Stage 2 hypertension (160–179 mm Hg/100–109 mm Hg)	173 (9.4)
Critical hypertension (≥180 mm Hg/≥110 mm Hg)	61 (3.3)
Unknown/missing	22 (1.2)
<b>Cholesterol</b>	
Hypocholesterolemia (0–49 mg/dL)	0
Normal (50–200 mg/dL)	1,324 (72.2)
Borderline (201–239 mg/dL)	238 (13.0)
High (≥240 mg/dL)	118 (6.4)
Unknown/missing	153 (8.3)
<b>Blood glucose</b>	
Low (0–70 mg/dL)	69 (3.8)
Normal (71–140 mg/dL)	1,470 (80.2)
Prediabetes (141–200 mg/dL)	113 (6.2)
Diabetes (≥201 mg/dL)	100 (5.5)
Unknown/missing	81 (4.4)
<b>Body mass index, kg/m<sup>2</sup></b>	
Underweight (<18.5)	0
Normal (18.5–24.9)	352 (19.2)
Overweight (25.0–29.9)	497 (27.1)
Obese (≥30.0)	901 (49.2)
Unknown/missing	83 (4.5)

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**Table 3. Knowledge Assessment Results of Adults Participating in the Arkansas Minority Barber & Beauty Shop Health Initiative (N = 1,833), Arkansas, 2016–2019**

Question	Correct Answer	Pretest, % Correct	Posttest, % Correct	P Value <sup>a</sup>	Percentage-Point Difference
<b>Multiple Choice</b>					
What should a normal blood pressure level be?	Top number <120	55.0	86.6	<.001	31.5
What should a normal blood pressure level be?	Bottom number <80	50.7	77.7	<.001	27.0
What is a normal total cholesterol level?	<200	44.6	87.9	<.001	43.3
If you thought someone was having a stroke or heart attack, what would be the first thing you should do?	Call 911	92.7	98.2	<.001	5.6
<b>Average correct</b>	–	60.8	87.6	–	26.8
<b>True or False</b>					
<b>The following are some symptoms of a stroke</b>					
Facial droop	True	90.4	98.5	<.001	8.1
Slurred speech	True	90.6	98.1	<.001	7.5
Weakness in arm or leg	True	89.9	95.1	<.001	5.2
<b>The following are some symptoms of a heart attack</b>					
Chest pain	True	94.1	97.4	<.001	3.3
Nausea/flu-like symptoms	True	70.4	90.0	<.001	19.6
Neck, back, and jaw pain	True	74.6	90.0	<.001	15.5
Shortness of breath	True	93.4	95.9	<.001	2.5
<b>Average correct</b>	–	86.2	95.0	–	8.8
<b>All</b>					
<b>Overall average correct</b>	–	76.9	92.3	–	15.4

<sup>a</sup> Differences between pretest and posttest determined by  $\chi^2$  test.

## SYSTEMATIC REVIEW

# Dose–Response Association Between High-Density Lipoprotein Cholesterol and Stroke: A Systematic Review and Meta-Analysis of Prospective Cohort Studies

Ranran Qie, MD<sup>1</sup>; Leilei Liu, MD<sup>1</sup>; Dongdong Zhang, MD<sup>2,3</sup>; Minghui Han, MD<sup>1</sup>;  
Bingyuan Wang, MD, PhD<sup>3,4</sup>; Yang Zhao, MD, PhD<sup>1</sup>; Dechen Liu, MD<sup>1</sup>;  
Chunmei Guo, MD<sup>1</sup>; Quanman Li, MD<sup>1</sup>; Qionggui Zhou, MD<sup>2,3</sup>; Gang Tian, MD<sup>1</sup>;  
Shengbing Huang, MD<sup>1</sup>; Xiaoyan Wu, MD<sup>2,3</sup>; Pei Qin, MD, PhD<sup>2,3</sup>; Jianxin Li, MD, PhD<sup>3,4</sup>;  
Jie Cao, MD, PhD<sup>3,4</sup>; Ming Zhang, MD, PhD<sup>2,3</sup>; Jianfeng Huang, MD, PhD<sup>3,4</sup>;  
Jie Lu, MD, PhD<sup>1</sup>; Dongsheng Hu, MD, PhD<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this subject?**

Previous epidemiologic studies reported that HDL-C protected against the development of stroke. However, several recent cohort studies found a positive association between HDL-C level and intracerebral hemorrhage. Also, whether a dose–response association between HDL-C level and stroke subtypes exists remains unclear.

**What is added by this report?**

Our results showed an 18% reduction in the relative risk of total stroke and a 24% reduction for ischemic stroke, but a 21% increase in intracerebral hemorrhage per 1-mmol/L increase in HDL-C level.

**What are the implications for public health practice?**

Reasonable control of HDL-C level will prevent and control incident stroke. Our findings may facilitate the development and promotion of blood lipid prevention strategies aimed at reducing stroke risk.

**Abstract****Introduction**

Studies investigating the effect of high-density lipoprotein cholesterol (HDL-C) on stroke and stroke subtypes have reached inconsistent conclusions. The purpose of our study was to clarify the dose–response association between HDL-C level and risk of total stroke and stroke subtypes by a systematic review and meta-analysis.

**Methods**

We performed a systematic search of PubMed, Embase, and Web of Science databases through July 30, 2020, for prospective cohort studies that reported the HDL-C–stroke association and extracted the estimate that was adjusted for the greatest number of confounding factors. Restricted cubic splines were used to evaluate the linear and nonlinear dose–response associations.

**Results**

We included 29 articles, which reported on 62 prospective cohort studies including 900,501 study participants and 25,678 with stroke. The summary relative risk per 1-mmol/L increase in HDL-C level for total stroke was 0.82 (95% CI, 0.76–0.89;  $I^2 = 42.9%$ ;  $n = 18$ ); ischemic stroke (IS), 0.75 (95% CI, 0.69–0.82;  $I^2 = 50.1%$ ;  $n = 22$ ); intracerebral hemorrhage (ICH), 1.21 (95% CI, 1.04–1.42;  $I^2 = 33.4%$ ;  $n = 10$ ); and subarachnoid hemorrhage (SAH), 0.98 (95% CI, 0.96–1.00;  $I^2 = 0%$ ;  $n = 7$ ). We found a linear inverse association between HDL-C level and risk of total



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stroke and SAH, a nonlinear inverse association for IS risk, but a linear positive association for ICH risk. The strength and the direction of the effect size estimate for total stroke, IS, ICH, and SAH remained stable for most subgroups. We found no publication bias with Begg's test and Egger's test for the association of HDL-C level with risk of total stroke, IS, and ICH.

### Conclusion

A high HDL-C level is associated with reduced risk of total stroke and IS and an increased risk of ICH.

## Introduction

Stroke is highly prevalent worldwide, and the number of people who experience stroke increased to more than 104.2 million in 2017 (1). From 1990 through 2017, the disability-adjusted life-years for stroke were about 132.0 million in 195 countries (2). Moreover, stroke is the second leading cause of death in the world, accounting for 6.2 million deaths globally in 2017. Of these deaths, about 2.7 million were due to ischemic stroke (IS), 3.0 million to intracerebral hemorrhage (ICH), and 0.5 million to subarachnoid hemorrhage (SAH) (3,4). However, much of the stroke burden could be prevented by managing and controlling modifiable risk factors.

Many prospective cohort studies reported that a high-density lipoprotein cholesterol (HDL-C) level protected against the development of stroke (5–11). However, the “good cholesterol” label for HDL-C has been challenged by several recent randomized controlled trials demonstrating that HDL-C-elevating therapy increased the risk of cardiovascular diseases (12,13). Thus, a full understanding of the effect of HDL-C level on stroke and stroke subtypes is warranted. Only one systematic review, conducted in 2008, examined the association between HDL-C level and risk of total stroke (14). Another meta-analysis in 2013 investigated the association between HDL-C level and risk of hemorrhagic stroke (15). However, up to 10 more cohort studies have been published recently on the association of HDL-C level with total stroke, ICH, and SAH, showing inconsistent results (9–11,16–24). No meta-analysis has been performed on the association of HDL-C level with IS, and a dose–response meta-analysis on the association of HDL-C level with total stroke and IS is lacking. We therefore performed this systematic review and dose–response meta-analysis of prospective cohort studies to quantitatively evaluate possible linear or nonlinear associations between baseline HDL-C level and risk of total stroke, IS, ICH, and SAH.

## Methods

### Data sources and searches

We followed the protocol for the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement for our meta-analysis (25). We conducted a systematic literature search of PubMed, Embase, and Web of Science databases for all reports of prospective cohort studies that examined the association between HDL-C level and stroke and were published through July 30, 2020, with no restriction on language. We also searched the reference lists of all related articles and reviews.

### Study selection

Two authors (R.Q. and M.H.) independently searched articles, selected relevant studies based on their title and abstract, then evaluated these articles by reviewing the full text. Inclusion criteria for prospective cohort studies were as follows: 1) study participants were aged  $\geq 18$  years; 2) the study investigated the association between HDL-C level and risk of stroke or stroke subtypes; 3) the study reported the effect estimates, relative risks (RRs), or hazard ratios (HRs), with 95% CIs for  $\geq 3$  HDL-C categories or per-unit increase in HDL-C level; and 4) the study reported the number of cases, exposed person-years, or participant numbers in each category of HDL-C level. We excluded cross-sectional and case-control studies, commentaries, letters, reviews, meta-analyses, and studies with unusable data. If data from the same study were reported more than once, only the most recent and complete data were included.

### Data extraction and quality assessment

R.Q. and L.L. independently extracted the following information from each study: first author, publication year, study name, study location, follow-up period, age range, sex, stroke and HDL-C assessment method, baseline levels of HDL-C, case number of per-category HDL-C exposure, total persons or person-years of per-category HDL-C exposure, reported RRs or HRs and 95% CIs for each HDL-C category, and adjusted covariates. Included studies were assessed for quality according to the 9-point Newcastle–Ottawa Quality Assessment Scale (NOS) (26). Any discrepancy was resolved by discussion with a senior investigator (D.H.).

We classified stroke, which included embolic infarction, large-artery occlusive infarction, lacunar infarction, and unclassified, as ICH, SAH, and IS (10). Some studies include all types of stroke for analysis and we call it total stroke in this meta-analysis. The lowest HDL-C category was the reference. For studies that did not choose the lowest category as the reference category, we reformulated RRs to set the lowest HDL-C category as the reference (27).

When HDL-C levels were reported in milligrams per deciliter (mg/dL), we used the scaling factor of 38.67 to translate 1-mg/dL HDL-C to 1-mmol/L HDL-C. Studies that provided results separately for men and women or reported multiple stroke subtypes within an article were treated as independent studies. For studies reporting results separately for fatal and nonfatal stroke, we combined the RRs and then included the pooled RR in the meta-analysis.

## Data synthesis and analysis

We considered the RR and 95% CI of the effect size for all studies. The reported HRs in the primary studies were considered equal to RRs (28). We first used the DerSimonian and Laird random-effects model, which considers both within-study and between-study variation, to calculate summary RRs and 95% CIs for high versus low HDL-C level (29). Studies reporting only a continuous risk estimate of stroke were excluded from our analysis. We then pooled the study-specific dose-response RRs and 95% CIs per 1-mmol/L increase in HDL-C level (29).

We used generalized least squares regression to estimate the study-specific dose-response association (30). The natural RRs and CIs across categories of HDL-C level were used to compute study-specific slopes (linear trends) and 95% CIs. A generalized least squares regression model estimates the linear dose-response coefficients and considers the covariance for each exposure category within each study because they are estimated relative to a common referent HDL-C level category. In this method, the distribution of cases and person-years, or cases and noncases, with the RRs and estimates of uncertainty (eg, CIs) for  $\geq 3$  quantitative categories of exposure were required. If studies reported only the total number of cases or person-years, the number of person-years or cases in each category was obtained from the total number of person-years or cases divided by the number of reported categories. We assigned the mean, median, or midpoint of HDL-C level in each category to the corresponding risk estimate. When the lowest or highest categories were open-ended, we assumed the width of the category to be the same as the closest category when estimating the midpoint (31). For the studies already reporting a linear dose-response trend for per n-mmol/L increase in HDL-C level, we calculated the dose-response RRs per 1-mmol/L increase in HDL-C level with this formula:  $RR_1 = \text{EXP}(\text{LN}(\text{RR}_n/n*1))$ , where  $RR_1$  represents the dose-response RRs for each 1-mmol/L increase in HDL-C level and  $RR_n$  represents the dose-response RRs for each n-mmol/L increase in HDL-C level (EXP: exponential function; LN: log base e) (32). All study-specific dose-response RR estimates were then pooled by using the DerSimonian and Laird random effects model (29). With heterogeneity ( $I^2$ )  $\geq 50\%$ , a random-effects model was used to calculate the summary RRs and 95% CIs; otherwise a fixed-effects model was used,

which considered both within- and between-study variation. The Hartung-Knapp-Sidik-Jonkman method was used to evaluate the stability of results for  $N < 10$  (33). A potential nonlinear association was examined by modeling HDL-C level by using restricted cubic splines with 3 knots located at the 25th, 50th, and 75th percentiles of the distribution (34). The  $P$  for nonlinearity was calculated by testing the null hypothesis that the coefficient of the second spline is equal to zero (35).

Heterogeneity was assessed by Cochran Q and  $I^2$  statistics (36). For the Q statistic,  $P < .10$  was considered significant. For the  $I^2$  statistic,  $I^2$  values of 0%, 25%, 50%, and 75% were considered to reflect no, low, moderate, and high heterogeneity, respectively. We also performed subgroup analyses by sex, region, follow-up period, publication year, sample size, and the covariates (alcohol drinking, education, body mass index, systolic blood pressure, physical activity, lipid-lowering medication use, and other lipid profile parameters) adjusted in the analysis.

A sensitivity analysis was performed to assess the influence of each individual study by omitting 1 study at a time and calculating a pooled estimate for the remainder of the studies (37). Potential publication bias was assessed with Egger's and Begg's tests (38,39). Conversion from DerSimonian-Laird results to Hartung-Knapp-Sidik-Jonkman results involved using Microsoft Excel software (Microsoft Corp). Other analyses were conducted with Stata 12.1 (Stata Corp), and all tests were 2-sided with a significance level of  $P < .05$ .

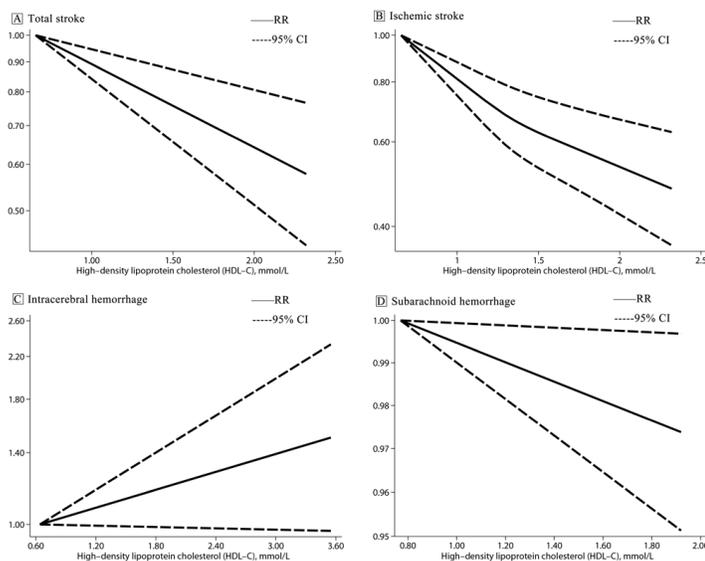
## Results

**Literature search and study characteristics.** Our literature search identified 7,366 articles; 1,113 were duplicates, leaving 6,253. After screening the titles and abstracts, we selected 201 potentially eligible articles. After detailed evaluation, we included 29 articles describing 62 prospective cohort studies in our meta-analysis with a total of 900,501 study participants of which 25,678 had stroke (5-11,16-24,40-52).

Eleven studies were conducted in Asia (including Iran and Israel) (7,8,10,17,18,20,21,23,24,46,52), 9 in the United States (9,19,22,40,42,44,48-50), 7 in Europe (5,11,16,41,43,47,51), and 2 in Australia (6,45). Three prospective cohorts included only men (5,51,52), another 3 included only women (8,40,49), and the rest included both sexes (Table 1). The mean NOS score was 8.24, which indicates the high quality of the articles included in the meta-analysis.

**HDL-C level and risk of total stroke.** To explore the association between HDL-C level and risk of total stroke, we examined 18 studies that included 256,427 participants overall and 12,328

people with stroke. We excluded 8 studies in comparing the highest versus lowest category of HDL-C because they provided only a continuous risk estimate. The pooled RR was 0.79 (95% CI, 0.72–0.87;  $I^2 = 46.4\%$ ;  $P_{\text{heterogeneity}} = .05$ ) (Table 2). The 18 studies were included in the dose–response analysis; the pooled RR for total stroke was 0.82 (95% CI, 0.76–0.89) per 1-mmol/L increase in HDL-C level, with low heterogeneity ( $I^2 = 42.9\%$ ;  $P_{\text{heterogeneity}} = .03$ ) (Table 3). We found a linear dose–response association between HDL-C level and risk of total stroke ( $P_{\text{nonlinearity}} = .96$ ) (Figure). No evidence of heterogeneity was detected between subgroups (Table 4). We observed an inverse association for most subgroups, except a nonsignificant association in studies of women, with a follow-up period of less than 10 years, without adjustment for physical activity or without adjustment for other lipid profile parameters (Table 4).



**Figure.** Linear dose–response association between high-density lipoprotein cholesterol and risk of stroke and stroke subtypes modeled with restricted cubic splines. Graph A shows total stroke; B, ischemic stroke; C, intracerebral hemorrhage; and D, subarachnoid hemorrhage.

**HDL-C level and risk of IS.** We included 10 studies consisting of a total of 706,482 participants and 19,047 people with stroke in the binary analysis of the association of IS risk with HDL-C level. The pooled RR was 0.75 (95% CI, 0.68–0.82;  $I^2 = 44.3\%$ ;  $P_{\text{heterogeneity}} = .06$ ; Table 2). Another 12 studies provided only a continuous risk estimate, so 22 studies were included in the dose–response analysis of IS risk. The pooled RR for IS was 0.75 (95% CI, 0.69–0.82) per 1-mmol/L increase in HDL-C level, with low heterogeneity ( $I^2 = 50.1\%$ ;  $P_{\text{heterogeneity}} = .004$ ) (Table 3). We found a nonlinear dose–response association between HDL-C

level and IS risk ( $P_{\text{nonlinearity}} = .13$ ) (Figure). No evidence of heterogeneity was detected between subgroups (Table 4). Subgroup analyses showed a nonsignificant association in studies with a sample size of less than 10,000.

**HDL-C level and risk of ICH.** Ten studies consisting of 246,607 participants overall and 1,467 people with ICH were included in the analysis of HDL-C level and risk of ICH. The summary RR was 1.13 (95% CI, 0.93–1.36;  $I^2 = 29.9\%$ ;  $P_{\text{heterogeneity}} = 0.17$ ) in the binary analysis (Table 2). The pooled results showed that risk of ICH was increased 26% per 1-mmol/L increase in HDL-C level (RR 1.21; 95% CI, 1.04–1.42), with low heterogeneity ( $I^2 = 33.4\%$ ,  $P_{\text{heterogeneity}} = 0.14$ ) (Table 3). We found a linear dose–response association between HDL-C level and risk of ICH ( $P_{\text{nonlinearity}} = 0.28$ ) (Figure). The effect size and direction of the pooled estimates were robust for most subgroups.

**HDL-C level and risk of SAH.** Data from 7 studies that included a total of 127,935 participants of which 551 had SAH provided information on the association between HDL-C level and risk of SAH. The pooled RR was 0.69 (95% CI, 0.50–0.95;  $I^2 = 30.7\%$ ;  $P_{\text{heterogeneity}} = 0.19$ ) (Table 2) in the binary analysis. With a per-1-mmol/L increase in HDL-C level, the pooled RR was 0.98 (95% CI, 0.96–1.00;  $I^2 = 0\%$ ;  $P_{\text{heterogeneity}} = 0.61$ ) (Table 3). Hartung-Knapp-Sidik-Jonkman results showed that risk of SAH was decreased 14% per 1-mmol/L increase in HDL-C level (RR 0.86; 95% CI, 0.75–0.98). We found a linear dose–response association between HDL-C level and risk of SAH ( $P_{\text{nonlinearity}} = 0.94$ ) (Figure). The pooled estimates remained relatively stable on subgroup analyses.

**Sensitivity analyses and publication bias.** In sensitivity analyses, the results were robust when excluding one study at a time in the analysis of total stroke, IS, ICH, and SAH. We found no publication bias with Begg’s test for risk of total stroke ( $P = 0.10$ ), IS ( $P = .15$ ), and ICH ( $P = .86$ ), and Egger’s test for risk of total stroke ( $P = .10$ ), IS ( $P = .31$ ), and ICH ( $P = .63$ ). Publication bias was not assessed for the association between HDL-C level and SAH because of limited studies.

## Discussion

We aimed to clarify the association between HDL-C level and risk of total stroke and stroke subtypes and found an inverse linear association between HDL-C level and risk of total stroke and IS. For each 1-mmol/L increase in HDL-C level, the risk of total stroke decreased by 18% and that of IS decreased by 24%. For ICH, we found a positive linear association, with the risk of ICH increased 21% per 1-mmol/L increase in HDL-C level. In addition, we found a marginal inverse linear association between HDL-C level and risk of SAH.

Results of previous reviews and meta-analyses evaluating the association between HDL-C level and total stroke, ICH, and SAH were consistent with our study (14,15). However, previous research suggesting a negative association between HDL-C level and total stroke was based on a review of 8 cohort studies and 3 case-control studies (14). Our review did not report the association between HDL-C level and stroke subtypes because of the limited data on that relationship (14). In the current meta-analysis, we quantitatively evaluated the possible linear or nonlinear association of HDL-C level with total stroke, IS, ICH, and SAH.

We found an inverse linear association between HDL-C level and risk of total stroke. The reduced risk of total stroke may be due to the anti-atherosclerotic effects of HDL-C (42). The oxidation of LDL is thought to play an important role in the development of atherosclerosis. HDL is a powerful antioxidant that exists in the subintimal space of the artery at a concentration 20 times greater than that of LDL and thus plays an important role in preventing atherosclerosis by inhibiting LDL oxidation in the artery wall (53). Additionally, HDL-C may play a central role in the reverse transport of cholesterol, thereby preventing the accumulation of excess cholesterol in peripheral tissues and the processes that initiate atherosclerosis (54). However, subgroup analyses by sex showed significantly decreased risk of total stroke in men but not in women. The reason behind such inference remains unknown, and future experimental studies are needed to explore the potential mechanism.

Among the 22 studies included for the association between HDL-C level and IS risk in the current meta-analysis (7,10,11,17,19–21,23,24,41,42,44,45,47,49–52,42,43,45,46,48,50–53), 16 showed an inverse association (7,10,11,19,20,23,24,41,42,47,49–52), 10 of which reached a significant level (7,10,11,24,41,42,47,51) while the remaining 6 showed no statistical significance (10,19,21,23,49,50). After pooling the 22 studies with a larger sample size, we observed a significant inverse nonlinear association between HDL-C level and IS. The main cause of IS is the formation of atherosclerotic plaque on the carotid artery wall (55). The anti-atherosclerotic effects and potent anti-inflammatory properties of HDL-C could explain our finding of a significant inverse association between HDL-C level and risk of IS (42). The main protein in HDL-C, apolipoprotein A-1, had a direct protective effect on atherosclerosis in several animal experiments (56,57). Besides, Kotur-Stevuljevic et al suggested that the increase in oxidative stress of HDL in patients after IS contributed to a decrease in the activity of the anti-oxidant enzyme paraoxonase 1 (55). Further research should confirm whether increasing HDL-C level through lifestyle changes or pharmacologic therapies will affect IS risk.

Compared with a previous meta-analysis of HDL-C level and hemorrhagic stroke (15), 5 cohort studies were additionally included in our meta-analysis of the association of HDL-C level and ICH risk. We found a positive linear association of HDL-C level and ICH risk, which agreed with the previous meta-analyses. The possible mechanisms are as follows. First, HDL also has an antithrombotic function. A high HDL-C level can increase the risk of ICH by promoting fibrinolysis (10), which was found to be associated with the inhibition of coagulation cascade and the stimulation of blood clot fibrinolysis (58). In addition, HDL attenuates platelet function by stimulating endothelial cells to produce nitric oxide and prostacyclin (58,59).

Results of a previous meta-analysis reported a significant positive association between HDL-C level and SAH based on 2 cohort studies (15). Five cohort studies were additionally included in our meta-analysis of HDL-C level and SAH risk. We found a marginal inverse linear association between HDL-C level and SAH risk. More large-sample cohort studies are needed to firmly establish this association.

Our meta-analysis has several strengths. To our knowledge, this is the first meta-analysis to systematically examine the association between HDL-C level and risk of major stroke subtypes by using both binary and dose–response analyses. Also, all included studies had a prospective design, large sample size, and long follow-up. In addition, the high mean NOS score, 8.24, indicated a relatively high quality of the articles included.

Our meta-analysis also had several limitations. First, IS is a mixed term, including lacunar infarction, large-artery occlusive infarction, and embolic infarction. Only 1 study explored the distinction between IS subtypes, so we could not explore the association between HDL-C level and each IS subtype (10). Second, most included studies did not exclude participants using medication, which may have confounded the association of HDL-C level with risk of total stroke and stroke subtypes. Third, HDL-C level was measured only at baseline, so we could not consider the effect of HDL-C changes during follow-up. Finally, all included studies were observational, and we need further analyses based on randomized clinical trials for assessing the causality of HDL-C level on stroke.

The effects of HDL cholesterol levels on stroke risk vary by type of stroke. A high HDL-C level was associated with reduced risk of total stroke and IS, but an increased risk of ICH. Reasonable control of HDL-C level will prevent and control incident stroke. However, because the HDL particle is so complex, we do not know whether the particle size, number, HDL-C content, or functionality is the best marker of stroke risk. Future studies with information on potential mechanisms are needed.

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## Author Information

Corresponding authors: Dongsheng Hu, Department of Epidemiology and Health Statistics, College of Public Health, Zhengzhou University, 100, Kexue Avenue, Gaoxin District, Zhengzhou, Henan 450001, People's Republic of China. Telephone: +86-755-86671951. Email: dongshenghu563@126.com. Jie Lu, Department of Epidemiology and Health Statistics, College of Public Health, Zhengzhou University, Zhengzhou, Henan, People's Republic of China. Telephone: +86-371-67781247. Email: hanyaa800@zzu.edu.cn.

Author Affiliations: <sup>1</sup>Department of Epidemiology and Health Statistics, College of Public Health, Zhengzhou University, Zhengzhou, Henan, People's Republic of China. <sup>2</sup>School of Public Health, Shenzhen University Health Science Center, Shenzhen, Guangdong, People's Republic of China. <sup>3</sup>Study Team of Shenzhen's Sanming Project, The Affiliated Luohu Hospital of Shenzhen University Health Science Center, Shenzhen, Guangdong, People's Republic of China. <sup>4</sup>Department of Epidemiology, Fuwai Hospital, National Center for Cardiovascular Diseases, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, People's Republic of China.

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Tables

**Table 1. Characteristics of Prospective Cohort Studies Reviewed, Dose–Response Association Between High-Density Lipoprotein Cholesterol and Stroke<sup>a</sup>**

Study	Country	Year	Age, y (SD) <sup>b</sup>	Follow-up, y	Sample Size, N (% Men)	Main Outcomes	NOS <sup>c</sup>
Watanabe et al (23)	Japan	2020	55.0 (13.4)	10.7	11,027 (38.9)	Total stroke, IS, ICH, SAH	9
Zhang et al (22)	US	2019	52.7	17	36,030 (44.5)	Total stroke	8
Gu et al (24)	China	2019	50.4 (11.6)	6–19	267,500 (59.6)	IS	9
Rist et al (40)	US	2019	≥45	19.3	27,937 (0)	ICH, SAH	9
Liu et al (21)	China	2019	20–80	3.6	42,005 (61.9)	Total stroke, IS	8
Saito et al (10)	Japan	2017	40–69	15	30,736 (34.4)	Total stroke, IS, ICH, SAH	8
Anne et al (41)	Norway	2017	≥30	12.8	27,936 (47.4)	IS	9
Harandi et al (18)	Iran	2016	≥35	10	6,323 (NA)	Total stroke	8
Glasser et al (19)	US	2016	≥45	6.9	23,867 (45.0)	Total stroke, IS	8
Hirata et al (20)	Japan	2016	≥30	18	7,019 (42.0)	Fatal total stroke, fatal IS	9
Pikula et al (42)	US	2015	64 (10)	9	6,276 (44.0)	IS	8
Reina et al (9)	US	2015	45–84	9.5	6,814 (47.0)	Total stroke	8
Tohidi et al (17)	Iran	2013	≥50	9.1	2,620 (46.0)	Total stroke, IS	8
Zhang et al (11)	Finland	2012	25–74	20.1	58,235 (NA)	Total stroke, IS, ICH, SAH	8
Wieberdink et al (43)	Netherlands	2011	58.8–68.5	9.7	5,773 (NA)	ICH	9
Hamer et al (16)	England	2011	NA	NA	13,778 (NA)	Fatal total stroke	7
Simons et al (45)	Australia	2009	≥60	16	2,805 (44.0)	IS	8
Willey et al (44)	US	2009	68.8 (10.3)	7.5	2,940 (36.5)	IS	7
Noda et al (46)	Japan	2009	40–79	10	91,219 (33.8)	Fatal ICH	9
Holme et al (47)	Sweden	2009	30–85	11.8	148,600 (56.5)	IS	8
Sturgeon et al (48)	US	2007	≥45	13.5	21,680 (44.2)	ICH	7
Kurth et al (49)	US	2007	≥45	11	27,937 (0)	IS	9
Psaty et al (50)	US	2004	≥65	7.5	4,885 (40.0)	IS	8
Curb et al (8)	Japan	2004	71–93	6.3	2,444 (0)	Total stroke	9
Soyama et al (7)	Japan	2003	35–79	10	4,989 (30.5)	Total stroke	9
Simons et al (6)	Australia	2001	≥60	10.8	2,805 (44.0)	Total stroke	8
Wannamethee et al (5)	England	2000	40–59	16.8	7,735 (100)	Total stroke	9
Leppala et al (51)	Finland	1999	50–69	6	28,519 (100.0)	ICH, SAH	7
Tanne et al (52)	Israel	1997	≥42	21	8,586 (100.0)	Fatal IS	8

Abbreviations: ICH, intracerebral hemorrhage; IS, ischemic stroke; NA, not available; NOS, Newcastle–Ottawa Scale; SAH, subarachnoid hemorrhage.

<sup>a</sup> Based on a systematic search of publications on PubMed, Embase, and Web of Science databases through July 30, 2020.

<sup>b</sup> Some articles reported mean age and SDs of included participants, and other articles reported only age range.

<sup>c</sup> The Newcastle–Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analysis (26).

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**Table 2. Risk Of Stroke And Stroke Subtypes With Highest Versus Lowest High-Density Lipoprotein Cholesterol, Systematic Review and Meta-Analysis of Prospective Cohort Studies**

Study (Reference Citation)	Sex	Study Year	Relative Risk (95% CI)	Weight (%) <sup>a</sup>
<b>Total stroke</b>				
Watanabe et al (23)	Men and women	2020	0.68 (0.49–0.95)	8.63
Zhang et al (22)	Men and women	2019	0.78 (0.63–0.96)	21.31
Saito et al (10)	Men	2017	0.78 (0.61–0.99)	16.12
Saito et al (10)	Women	2017	0.93 (0.73–1.17)	16.99
Hirata et al (20)	Men and women	2016	1.39 (0.67–2.89)	1.77
Zhang et al (11)	Men	2012	0.98 (0.75–1.27)	13.63
Zhang et al (11)	Women	2012	0.70 (0.53–0.93)	11.96
Curb et al (8)	Men	2000	0.37 (0.17–0.81)	1.55
Soyama et al (7)	Men and women	2003	0.35 (0.16–0.74)	1.61
Wannamethee et al (5)	Men	2000	0.68 (0.46–0.99)	6.44
Overall <sup>b</sup>	–	–	0.79 (0.72–0.87)	100.0
<b>Ischemic stroke</b>				
Watanabe et al (23)	Men and women	2020	0.75 (0.50–1.12)	4.89
Gu et al (24)	Men and women	2019	0.79 (0.69–0.90)	45.06
Saito et al (10)	Men	2017	0.72 (0.53–0.98)	8.42
Saito et al (10)	Women	2017	0.73 (0.53–1.01)	7.65
Tohidi et al (17)	Men and women	2017	1.25 (0.48–3.29)	0.86
Zhang et al (11)	Men	2012	1.05 (0.77–1.42)	8.49
Zhang et al (11)	Women	2012	0.55 (0.40–0.76)	7.72
Kurth et al (49)	Women	2007	0.82 (0.55–1.23)	4.91
Soyama et al (7)	Men and women	2003	0.34 (0.14–0.86)	0.97
Leppala et al (51)	Men	1999	0.59 (0.45–0.77)	11.03
Overall <sup>c</sup>	–	–	0.75 (0.68–0.82)	100.0
<b>Intracerebral hemorrhage</b>				
Watanabe et al (23)	Men and women	2020	0.53 (0.25–1.14)	6.05
Rist et al (40)	Women	2019	0.98 (0.45–2.13)	5.76
Saito et al (10)	Men	2017	0.81 (0.52–1.28)	17.16
Saito et al (10)	Women	2017	1.72 (1.08–2.74)	16.06
Zhang et al (11)	Men	2012	0.98 (0.52–1.86)	8.57
Zhang et al (11)	Women	2012	2.14 (0.91–5.05)	4.74
Wieberdink et al (43)	Men and women	2011	1.29 (0.48–3.45)	3.58
Noda et al (46)	Men and women	2009	0.98 (0.62–1.53)	17.06
Sturgeon et al (48)	Men and women	2007	1.39 (0.62–2.25)	15.05

Abbreviation: –, not applicable.

<sup>a</sup> Weight = the proportion of the result of each article in the summary results.

<sup>b</sup>  $I^2 = 46.4\%$ ;  $P = .05$ .

<sup>c</sup>  $I^2 = 44.3\%$ ;  $P = 0.06$ .

<sup>d</sup>  $I^2 = 29.9\%$ ;  $P = 0.17$ .

<sup>e</sup>  $I^2 = 30.7\%$ ;  $P = 0.19$ .

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**Table 2. Risk Of Stroke And Stroke Subtypes With Highest Versus Lowest High-Density Lipoprotein Cholesterol, Systematic Review and Meta-Analysis of Prospective Cohort Studies**

Study (Reference Citation)	Sex	Study Year	Relative Risk (95% CI)	Weight (%) <sup>a</sup>
Leppala et al (51)	Men	1999	1.33 (0.62–2.85)	5.98
Overall <sup>d</sup>	–	–	1.13 (0.93–1.36)	100.0
<b>Subarachnoid hemorrhage</b>				
Watanabe et al (23)	Men and women	2020	0.64 (0.27–1.55)	13.18
Rist et al (40)	Women	2019	1.01 (0.33–3.08)	8.07
Saito et al (10)	Men	2017	1.23 (0.47–3.24)	10.80
Saito et al (10)	Women	2017	0.73 (0.40–1.34)	27.55
Zhang et al (11)	Men	2012	0.56 (0.25–1.25)	15.55
Zhang et al (11)	Women	2012	1.27 (0.50–3.28)	11.38
Leppala et al (51)	Men	1999	0.26 (0.11–0.62)	13.47
Overall <sup>e</sup>	–	–	0.69 (0.50–0.95)	100.0

Abbreviation: –, not applicable.

<sup>a</sup> Weight = the proportion of the result of each article in the summary results.

<sup>b</sup>  $I^2 = 46.4\%$ ;  $P = .05$ .

<sup>c</sup>  $I^2 = 44.3\%$ ;  $P = 0.06$ .

<sup>d</sup>  $I^2 = 29.9\%$ ;  $P = 0.17$ .

<sup>e</sup>  $I^2 = 30.7\%$ ;  $P = 0.19$ .

**Table 3. Relative Risk For Stroke And Stroke Subtypes in Relation to High-Density Lipoprotein Cholesterol Levels, Systematic Review and Meta-Analysis of Prospective Cohort Studies**

Study	Sex	Year	Relative Risk (95% CI) <sup>a</sup>	Weight (%) <sup>b</sup>
<b>Total stroke</b>				
Watanabe et al (23)	Men and women	2020	0.69 (0.50–0.95)	6.12
Zhang et al (22)	Men and women	2019	0.81 (0.67–0.96)	19.49
Liu et al (21)	Men	2019	0.86 (0.62–1.19)	5.93
Liu et al (21)	Women	2019	1.19 (0.73–1.94)	2.64
Saito et al (10)	Men	2017	0.75 (0.58–0.97)	9.38
Saito et al (10)	Women	2017	0.92 (0.71–1.19)	9.34
Harandi et al (18)	Men and women	2016	0.92 (0.63–1.34)	4.43
Glasseret et al (19)	Men and women	2016	0.93 (0.78–1.10)	21.24
Hirata et al (20)	Men and women	2016	0.86 (0.38–1.93)	0.95
Reina et al (9)	Men and women	2015	0.56 (0.31–0.99)	1.90
Tohidi et al (17)	Men and women	2013	1.11 (0.44–2.78)	0.74
Zhang et al (11)	Men	2012	1.01 (0.66–1.53)	3.60
Zhang et al (11)	Women	2012	0.47 (0.30–0.74)	3.21
Hamer et al (16)	Men and women	2011	1.13 (0.75–1.68)	3.88
Curb et al (8)	Men	2004	0.20 (0.06–0.72)	0.39
Soyama et al (7)	Men and women	2003	0.48 (0.25–0.93)	1.46
Simons et al (6)	Men and women	2001	0.63 (0.42–0.95)	3.83
Wannamethee et al (5)	Men	2000	0.48 (0.25–0.93)	1.46
Overall <sup>c</sup>	–	–	0.82 (0.76–0.89)	100.0
<b>Ischemic stroke</b>				
Watanabe et al (23)	Men and women	2020	0.76 (0.51–1.12)	3.55
Gu et al (24)	Men and women	2019	0.75 (0.67–0.83)	10.89
Liu et al (21)	Men	2019	0.83 (0.57–1.21)	3.74
Liu et al (21)	Women	2019	1.14 (0.67–1.93)	2.21
Saito et al (10)	Men	2017	0.68 (0.49–1.01)	4.48
Saito et al (10)	Women	2017	0.70 (0.49–1.01)	3.98
Anne et al (41)	Men and women	2017	0.78 (0.66–0.92)	8.80
Glasser et al (19)	Men and women	2016	0.88 (0.72–1.07)	7.65
Hirata et al (20)	Men and women	2016	1.15 (0.65–2.04)	1.94
Pikula et al (42)	Men and women	2015	0.51 (0.37–0.70)	4.71
Tohidi et al (17)	Men and women	2013	1.44 (0.54–3.84)	0.73
Zhang et al (11)	Men	2012	1.02 (0.62–1.66)	2.47

Abbreviation: —, not applicable.

<sup>a</sup> subtypes per 1-mmol/L increase in high-density lipoprotein cholesterol

<sup>b</sup> Weights are from random effects analysis.

<sup>c</sup>  $I^2 = 42.9\%$ ;  $P = .03$ .

<sup>d</sup>  $I^2 = 50.1\%$ ;  $P = .004$ .

<sup>e</sup>  $I^2 = 33.4\%$ ;  $P = .14$ .

<sup>f</sup>  $I^2 = 0.0\%$ ;  $P = .61$ .

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**Table 3. Relative Risk For Stroke And Stroke Subtypes in Relation to High-Density Lipoprotein Cholesterol Levels, Systematic Review and Meta-Analysis of Prospective Cohort Studies**

Study	Sex	Year	Relative Risk (95% CI) <sup>a</sup>	Weight (%) <sup>b</sup>
Zhang et al (11)	Women	2010	0.35 (0.21–0.59)	2.29
Simons et al (45)	Men and women	2010	1.10 (0.65–1.87)	2.21
Willey et al (44)	Men and women	2009	1.08 (0.67–1.66)	2.80
Holme et al (47)	Men	2009	0.79 (0.71–0.86)	11.26
Holme et al (47)	Women	2009	0.67 (0.59–0.73)	10.91
Kurth et al (49)	Women	2007	0.83 (0.53–1.30)	2.90
Psaty et al (50)	Men and women	2004	0.81 (0.60–1.10)	4.90
Soyama et al (7)	Men and women	2003	0.45 (0.21–1.00)	1.09
Leppala et al (51)	Men	1999	0.54 (0.39–0.75)	4.49
Tanne et al (52)	Men	1997	0.55 (0.31–0.93)	2.04
Overall <sup>d</sup>	—	—	0.75 (0.69–0.82)	100.0
<b>Intracerebral hemorrhage</b>				
Watanabe et al (23)	Men and women	2020	0.59 (0.28–1.21)	4.72
Rist et al (40)	Women	2019	0.99 (0.47–2.09)	4.53
Saito et al (10)	Men	2017	0.79 (0.49–1.28)	10.91
Saito et al (10)	Women	2017	1.69 (1.05–2.73)	11.01
Zhang et al (11)	Men	2012	1.13 (0.41–3.07)	2.51
Zhang et al (11)	Women	2012	2.64 (0.67–10.42)	1.34
Wieberdink et al (43)	Men and women	2011	1.16 (0.84–1.61)	23.91
Noda et al (46)	Men and women	2009	1.19 (0.82–1.74)	17.75
Sturgeon et al (48)	Men and women	2007	1.69 (1.17–2.41)	19.23
Leppala et al (51)	Men	1999	1.08 (0.49–2.36)	4.10
Overall <sup>e</sup>	—	—	1.21 (1.04–1.42)	100.0
<b>Subarachnoid hemorrhage</b>				
Watanabe et al (23)	Men and women	2020	0.64 (0.28–1.49)	0.06
Rist et al (40)	Women	2019	1.02 (0.35–2.97)	0.04
Saito et al (10)	Men	2017	1.53 (0.53–4.41)	0.04
Saito et al (10)	Women	2017	0.98 (0.96–1.00)	99.79
Zhang et al (11)	Men	2012	0.67 (0.19–2.35)	0.03
Zhang et al (11)	Women	2012	1.09 (0.24–4.91)	0.02
Leppala et al (51)	Men	1999	0.41 (0.14–1.23)	0.03
Overall <sup>f</sup>	—	—	0.98 (0.96–1.00)	100.0

Abbreviation: —, not applicable.

<sup>a</sup> subtypes per 1-mmol/L increase in high-density lipoprotein cholesterol

<sup>b</sup> Weights are from random effects analysis.

<sup>c</sup>  $I^2 = 42.9\%$ ;  $P = .03$ .

<sup>d</sup>  $I^2 = 50.1\%$ ;  $P = .004$ .

<sup>e</sup>  $I^2 = 33.4\%$ ;  $P = .14$ .

<sup>f</sup>  $I^2 = 0.0\%$ ;  $P = .61$ .

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**Table 4. Dose–Response Subgroup Analyses of Association Between High-Density Lipoprotein Cholesterol and Risk of Total Stroke and Ischemic Stroke, Systematic Review and Meta-Analysis of Prospective Cohort Studies**

Characteristics	Total Stroke				Ischemic Stroke			
	No. of Studies	Relative Risk (95% CI)	<i>I</i> <sup>2</sup>	<i>P</i> Value <sup>a</sup>	No. of Studies	Relative Risk (95% CI)	<i>I</i> <sup>2</sup>	<i>P</i> Value <sup>a</sup>
<b>All studies</b>	18	0.82 (0.76–0.89)	42.9	.03	22	0.75 (0.69–0.82)	50.1	.004
<b>Sex</b>								
Men/women	7	0.82 (0.70–0.96)	41.8	.11	8	0.78 (0.68–0.89)	51.0	.046
Men	8	0.79 (0.64–0.99)	31.9	.17	9	0.76 (0.65–0.90)	39.6	.10
Women	6	0.74 (0.52–1.04)	60.0	.03	8	0.71 (0.56–0.88)	49.7	.05
<b>Region</b>								
Asian	10	0.81 (0.70–0.95)	28.6	.18	10	0.76 (0.68–0.85)	8.0	.37
Non-Asian	8	0.77 (0.63–0.93)	59.2	.02	12	0.74 (0.66–0.84)	65.8	.001
<b>Follow-up period</b>								
<10 years	7	0.92 (0.81–1.05)	44.4	.10	9	0.78 (0.66–0.91)	57.7	.03
≥10 years	11	0.77 (0.70–0.85)	31.3	.15	13	0.74 (0.66–0.82)	47.2	.03
<b>Publication year</b>								
≤2010	4	0.53 (0.39–0.72)	4.6	.37	8	0.72 (0.63–0.82)	51.1	.05
>2010	14	0.85 (0.78–0.92)	27.0	.17	14	0.77 (0.68–0.87)	51.5	.01
<b>Sample size</b>								
<10,000	8	0.67 (0.55–0.82)	30.4	.19	8	0.79 (0.60–1.05)	59.0	.004
≥10,000	10	0.85 (0.78–0.93)	41.2	.08	14	0.75 (0.68–0.81)	47.9	.02
<b>Alcohol drinking</b>								
No	6	0.88 (0.79–0.98)	6.5	.38	8	0.74 (0.66–0.83)	59.1	.02
Yes	12	0.76 (0.68–0.85)	48.0	.03	14	0.76 (0.66–0.88)	47.8	.02
<b>Education</b>								
No	13	0.80 (0.71–0.91)	31.8	.12	15	0.74 (0.68–0.81)	34.6	.09
Yes	5	0.74 (0.52–1.05)	71.3	.02	7	0.76 (0.62–0.95)	70.4	.002
<b>Body mass index</b>								
No	6	0.89 (0.78–1.02)	29.2	.22	6	0.80 (0.70–0.91)	59.4	.03
Yes	12	0.78 (0.71–0.87)	46.3	.04	16	0.72 (0.64–0.81)	48.6	.02
<b>Systolic blood pressure</b>								
No	6	0.82 (0.71–0.94)	45.3	.10	6	0.74 (0.65–0.84)	67.6	.009
Yes	12	0.82 (0.74–0.90)	46.7	.04	16	0.76 (0.67–0.86)	42.3	.04
<b>Physical activity</b>								
No	10	0.87 (0.74–1.01)	23.6	.23	12	0.76 (0.68–0.84)	52.9	.02
Yes	8	0.73 (0.61–0.88)	53.7	.04	10	0.74 (0.63–0.88)	51.8	.03
<b>Lipid lowering medication use</b>								
No	9	0.69 (0.53–0.91)	59.2	.01	14	0.72 (0.65–0.80)	61.6	.001
Yes	9	0.85 (0.77–0.93)	3.6	.41	8	0.83 (0.73–0.93)	0	.62
<b>Other lipid profiles parameters</b>								

<sup>a</sup> Based on the DerSimonian and Laird random-effects model.

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(continued)

**Table 4. Dose–Response Subgroup Analyses of Association Between High-Density Lipoprotein Cholesterol and Risk of Total Stroke and Ischemic Stroke, Systematic Review and Meta-Analysis of Prospective Cohort Studies**

Characteristics	Total Stroke				Ischemic Stroke			
	No. of Studies	Relative Risk (95% CI)	<i>I</i> <sup>2</sup>	<i>P</i> Value <sup>a</sup>	No. of Studies	Relative Risk (95% CI)	<i>I</i> <sup>2</sup>	<i>P</i> Value <sup>a</sup>
No	10	0.84 (0.69–1.03)	55.2	.02	12	0.75 (0.67–0.84)	61.0	.003
Yes	8	0.77 (0.69–0.86)	0	.47	10	0.75 (0.64–0.87)	34.9	.13

<sup>a</sup> Based on the DerSimonian and Laird random-effects model.

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## ORIGINAL RESEARCH

# Racial/Ethnic and Geographic Variations In Long-Term Survival Among Medicare Beneficiaries After Acute Ischemic Stroke

Xin Tong, MPH<sup>1</sup>; Linda Schieb, MPH<sup>1</sup>; Mary G. George, MD, MSPH<sup>1</sup>;  
Cathleen Gillespie, MS<sup>1</sup>; Robert K. Merritt, MA<sup>1</sup>; Quanhe Yang, PhD<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known about this subject?**

Many studies showed a racial/ethnic disparity in stroke risk factors, hospitalizations, incidence, and mortality among older patients with stroke.

**What is added by this report?**

We assessed the long-term survival of older patients after hospitalization with acute ischemic stroke and identified the significant racial/ethnic and geographic variations.

**What are the implications for public health practice?**

Prevention strategies need to be developed to reduce the disparities in stroke treatment and access to health care, especially among minority racial/ethnic groups.

## Abstract

**Introduction**

Little information is available about racial/ethnic and geographic variations in long-term survival among older patients ( $\geq 65$ ) after acute ischemic stroke (AIS).

**Methods**

We examined data on 1,019,267 Medicare fee-for-service (FFS) beneficiaries aged 66 or older, hospitalized with a primary diagnosis of AIS from 2008 through 2012. Survival was defined as the time from the date of AIS to date of death, or an end of follow-

up date of December 31, 2017. We used Cox proportional hazard models to estimate 5-year survival after AIS, adjusted for age, sex, race and Hispanic ethnicity, poverty level, Charlson Comorbidity Index, and state.

**Results**

Among 1,019,267 Medicare FFS beneficiaries hospitalized with AIS from 2008 through 2012, we documented 701,718 deaths (68.8%) during a median of 4 years of follow-up with 4.08 million person-years. The overall adjusted 5-year survival was 44%. Non-Hispanic Black men had the lowest 5-year survival, and 5-year survival varied significantly by state, from the highest at 49.1% (North Dakota) to the lowest at 40.5% (Hawaii). The ranges between the highest and lowest 5-year survival rates across states also varied significantly by racial/ethnic groups, with percentage point differences of 9.6 among non-Hispanic White, 11.3 among non-Hispanic Black, 17.7 among Hispanic, and 28.5 among other racial/ethnic beneficiaries.

**Conclusion**

We identified significant racial/ethnic and geographic variations in 5-year survival rates after AIS among 2008–2012 Medicare FFS beneficiaries. Further study is needed to understand the reasons for these variations and develop prevention strategies to improve survival and racial disparities in survival after AIS.

## Introduction

Stroke is the fifth leading cause of death in the United States with approximately 795,000 new or recurrent acute strokes occurring every year. The annual direct medical cost for stroke was estimated at \$30.8 billion from 2016 through 2017 (1). Although stroke risks and mortality have declined considerably, racial/ethnic and geographic disparities remain significant (1). Recent studies suggest that the decline in stroke mortality stalled in recent years and that demographic and geographic variations remained substantial



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(2,3). However, limited studies examined the long-term survival after stroke and racial/ethnic and geographic variations in stroke survival among older adults (defined as  $\geq 65$  y) in the United States.

The aim of our study was to assess long-term (5-year) survival among patients aged 66 or older after acute ischemic stroke (AIS) and to examine racial/ethnic differences and geographic variations in stroke survival. Our findings may provide information to improve survival and reduce survival disparities after stroke among older adults in the United States.

## Methods

### Data sources and study sample

We used Medicare's enrollment databases to generate our study cohort among Medicare fee-for-service (FFS) beneficiaries and Medicare Provider Analysis and Review (MEDPAR) data to assess overall survival among beneficiaries hospitalized with AIS from 2008 through 2012. To select the final analytical cohort we 1) identified all Medicare FFS beneficiaries aged 65 or older with 12 months continuous enrolment in Medicare parts A and B during 2007–2012; 2) identified all hospitalizations with AIS as the primary diagnosis among FFS beneficiaries from 2007 through 2012, including multiple admissions; and 3) used a 12-month or longer lookback period to identify the first AIS hospitalization. The length of lookback time varied by the years of Medicare enrollment; for example, 12 months for beneficiaries aged 66 (Medicare eligible at age 65 years), 24 months for those aged 67, and so on. Because of the 12-month or longer lookback period, our final cohort included FFS beneficiaries aged 66 or older with AIS hospitalizations from 2008 through 2012 (2007 served as lookback time). We used MEDPAR files to identify AIS, our outcome of interest. The MEDPAR files contained records for inpatient hospital stays and skilled nursing facility stays for all Medicare beneficiaries, and we used the primary diagnosis codes (International Classification of Diseases, 9th revision [ICD-9-CM] [4] codes 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, and 434.91) to identify beneficiaries with AIS. We excluded all institutional long-term stay hospitalizations. We identified 1,019,267 FFS beneficiaries aged 66 or older in our study period who had AIS. Socioeconomic status (SES) in the community, defined by the percentage below the poverty level in the county of beneficiary residence in 2008, was linked to Medicare data from the Health Resources and Services Administration Area Health Resources Files (<https://data.hrsa.gov/data/download>).

### Statistical methods

We examined differences in the distribution of demographic features by  $\chi^2$  test for categorical variables, and *t* test for continuous variables. The 5-year survival was defined as the time from the date of AIS to the date of death, or the date of end of follow-up (December 31, 2017), whichever came first. We used the National Death Index linked to Medicare data available through the Centers for Medicare and Medicaid Services (CMS) to determine the date of death. We performed 5-year survival analyses and subgroup analyses by age groups (66–74, 75–84, and  $\geq 85$ ), sex, race and Hispanic ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and other non-Hispanic races), and SES at the county level (quartile distribution; higher quartiles indicate higher level of poverty). We identified Charlson Comorbidity Index (CCI) conditions (5) by using secondary diagnosis codes. We examined the variations in AIS survival across the states for all beneficiaries and by race and Hispanic ethnicity. Univariate and multivariate survival analyses of 5-year survival after AIS were carried out using the Kaplan–Meier life table, and Cox proportional hazards regression analyses adjusting for age, sex, race and Hispanic ethnicity, SES, state (Model 1); and for CCI (0, 1, 2, 3, and  $\geq 4$ ) (Model 2). For subgroup analyses, we defined insufficient data if the total events (deaths) per analytic group were fewer than 15 during follow-up. We used SAS, version 9.4 (SAS Institute) for analyses and considered a 2-sided *P* value of  $<.05$  significant. Medicare data are available from CMS, US Department of Health and Human Services, for any qualified investigator.

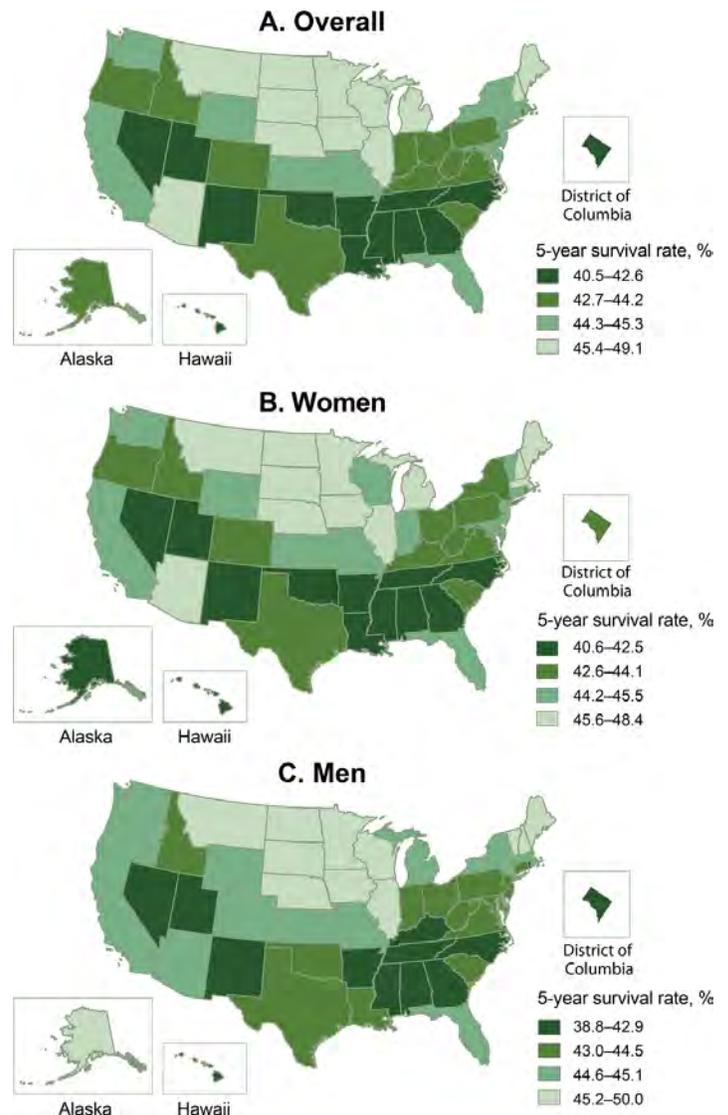
## Results

From 2008 through 2012, AIS was the primary reason for hospitalization of 1,019,267 Medicare FFS beneficiaries (Table 1). Their median age at AIS admission was 79.9 (interquartile range [IQR], 73.5–85.8), 31% were aged 66–74, 41% were 75–84, and 28% were 85 or older. Forty-four percent of those FFS beneficiaries were men and 84% were non-Hispanic White. A quarter of AIS beneficiaries had no comorbidity as defined by CCI, and 14% had 4 or more comorbidities. Compared with other racial/ethnic groups, non-Hispanic Black AIS beneficiaries had a higher percentage of those who were aged 66 to 74 (41%), women (61%), had household incomes 75% below the poverty level (41%), or had 4 or more CCI comorbidity conditions (21%).

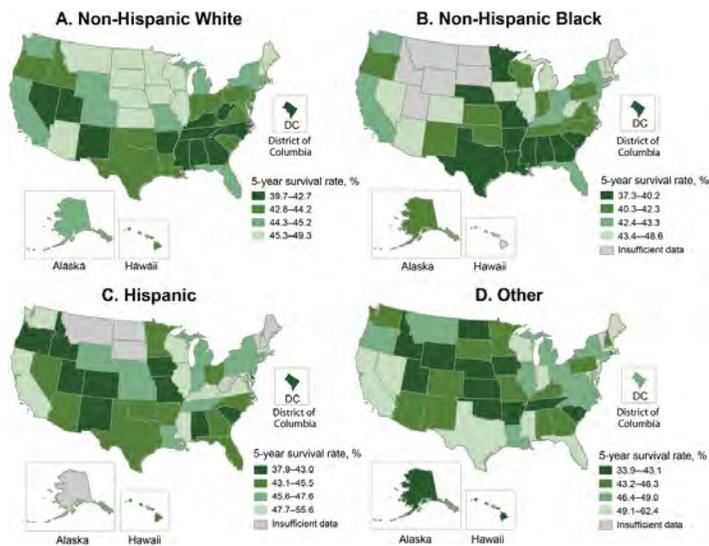
Overall, 701,718 (68.8%) beneficiaries with AIS died after hospitalization during a median of 4.0 years follow-up with a total of 4.08 million person-years. Crude overall 5-year survival was 43.7%, and adjusted survival was 44.1% (Model 1) and 44.0% (Model 2) (Table 2). The adjusted 5-year survival rate decreased significantly with increasing age and was similar for men and wo-

men (44%). We saw noticeable differences in survival by race and Hispanic ethnicity and county-level SES. Non-Hispanic Black beneficiaries had the lowest crude 5-year survival (41.4%) but had a comparable adjusted 5-year survival compared with non-Hispanic White beneficiaries (43.6% vs 43.8%, Model 2); Hispanic and other races/ethnicities remained stable compared with the crude estimates. By looking at sex-specific estimates by race and Hispanic ethnicity, non-Hispanic Black men (40.8%) and non-Hispanic White women (43.4%) had the lowest adjusted survival (Model 2) compared with the people of other races/ethnicities and Hispanic ethnicity. The 5-year survival rate decreased as county levels of poverty increased.

The adjusted 5-year survival rates following AIS varied significantly across the states. Hawaii had the lowest 5-year survival rate (40.5%), Alabama had the second lowest (40.8%), and North Dakota (49.1%) and South Dakota (48.6%) had the highest (Figure 1) (Table 3). Several stroke belt (6) and southern states (Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, and Tennessee) were among the states with the 15 lowest survival rates (range 40.8%– 42.7%). The lowest survival rate observed among non-Hispanic Black beneficiaries was in some states in the Midwest and the Southeast, and the highest survival rates were among states in the West and Northeast (Figure 2). However, for non-Hispanic White beneficiaries, the highest survival rates were in the Midwestern states, and the lowest survival rates were mainly in the Southeast. The survival pattern for Hispanic beneficiaries and those of other races/ethnicities was different from that of non-Hispanic White and non-Hispanic Black beneficiaries, with the lowest survival rates scattered outside of the Southeast. We saw substantial differences in 5-year survival rates across the states among each race and Hispanic ethnicity. Among non-Hispanic White groups, survival rates ranged from the highest, 49.3%, in North Dakota to the lowest, 39.7%, in the District of Columbia, a 9.6 percentage point difference. For non-Hispanic Black groups, it ranged from 48.6% in Arizona to 37.3% in Minnesota, an 11.3 percentage point difference. For Hispanic groups, the rate was 55.6% in Mississippi and 37.9% in Delaware, with a 17.7 percentage point difference. Other races/ethnicities had a difference of 28.5 percentage points in survival rates across the states, with the highest rate in Delaware, 62.4%, and the lowest rate in Idaho, 33.9%.



**Figure 1.** Adjusted 5-year survival after acute ischemic stroke among Medicare fee-for-service beneficiaries, Medicare cohort 2008–2017. Map A shows the adjusted 5-year survival after acute ischemic stroke among all Medicare fee-for-service beneficiaries. Map B shows the adjusted 5-year survival among women, and Map C shows the adjusted 5-year survival among men.



**Figure 2.** Adjusted 5-year survival after acute ischemic stroke by race and Hispanic ethnicity among Medicare fee-for-service beneficiaries, Medicare cohort 2008–2017. Map A shows the adjusted 5-year survival after acute ischemic stroke among non-Hispanic White Medicare beneficiaries. Map B shows the adjusted 5-year survival among non-Hispanic Black beneficiaries. Map C shows the adjusted 5-year survival among Hispanic Medicare beneficiaries. Map D shows the adjusted 5-year survival among other (other non-Hispanic races) Medicare beneficiaries. Abbreviation: –, insufficient data.

## Discussion

Our study’s findings suggested that about 2 in 5 Medicare FFS beneficiaries aged 66 or older survived at least 5 years after hospitalization for AIS. Men and women had similar 5-year survival. We found significant racial/ethnic and geographic variations in 5-year survival after AIS. Non-Hispanic Black men had the lowest adjusted 5-year survival. Non-Hispanic White beneficiaries overall had the least variation in adjusted 5-year survival across states; other races/ethnicities had the greatest variation.

Many studies reported racial disparities in stroke risk factors and in stroke hospitalizations, incidence, and mortality (7–9), but few focused on long-term survival after stroke. An early study using Medicare data suggested that non-Hispanic Black people aged 65 or older, especially men, had significantly lower survival after stroke than non-Hispanic White people, consistent with our findings (10). Yao et al recently reported that Black Medicare beneficiaries were at higher risk for ischemic stroke than White beneficiaries and more likely to have diabetes or obesity (7). The Northern Manhattan Stroke study suggested that Black and Caribbean Hispanic people had more stroke risk factors than White people in their community-based multiethnic population study (8). The Reasons for Geographic and Racial Differences in Stroke (REGARDS) study reported that Black people had a greater age- and

sex-adjusted mean 10-year predicted stroke risk than White people, which contributed to disparities in stroke mortality (9). Reports from the REGARDS study suggested that although management of acute stroke appeared to be more equivalent between Black and White participants, the racial disparity in stroke mortality was largely driven by differences in stroke incidence (11). Stroke mortality mainly depends on the incidence of stroke associated with the stroke risk profiles in a population (11,12), and stroke survival depends on prestroke morbidity and frailty, comorbid conditions, severity of stroke, access to stroke treatment, and quality of care (13,14). Therefore, a population with a higher stroke risk profile, incidence, and mortality could have a better survival rate after stroke than those from a population with lower stroke incidence and mortality. Our findings showed that the crude difference in survival between non-Hispanic White and non-Hispanic Black populations, especially among women, became insignificant after adjusting for demographics, SES, and CCI, suggesting the importance of prestroke comorbidities (Model 1 vs Model 2) in explaining racial differences in stroke survival. Further studies are needed to examine the relative contribution of stroke risk factors, prestroke morbidity and frailty, treatments, and care to racial disparities in stroke survival.

Our study found that Medicare FFS beneficiaries in the southeastern United States region had the lowest 5-year survival following AIS. The findings of recent studies showed significant geographic variations in stroke death rates at the county level, and in the long-established stroke belt in the Southeast (15,16). In addition, a study based on 2000–2002 Medicare FFS beneficiaries discharged with an incident ischemic stroke reported that the highest recurrent stroke rates occurred in the southern regions (17).

Our study suggested that the differences in 5-year survival after AIS across the states appeared to be wider for Hispanic people and other races compared with non-Hispanic White and non-Hispanic Black people. The difference between the highest and the lowest survival rates across the states ranged from 9.6 to 28.5 percentage points by race and Hispanic ethnicity. Reasons for these significant differences are not clear. Among Hispanic beneficiaries, the top 5 highest 5-year survival rates were in Massachusetts (49.3%), Washington (50.6%), Maryland (52.0%), Kentucky (52.2%), and Mississippi (55.6%), whereas the 5 lowest survival rates were in Oregon (41.3%), Colorado (40.6%), Alabama (39.7%), Missouri (38.2%), and Delaware (37.9%). With the rapid growth of the Hispanic population in the United States (18,19), there may be a gap in assessing stroke risk factors, access to health care, and promoting stroke prevention programs across the states among Hispanic residents. Samet et al reported a notably high proportion of Hispanic adults in Texas with obesity and diabetes (20). The study, which was conducted between 2008 and 2011 and included 15,079

Hispanic participants, reported the pervasive burden of cardiovascular disease risk factors among Hispanic participants and identified the risk factors (hypertension, diabetes, and smoking) associated with stroke (21). Other studies reported significant disparities in stroke care among racial/ethnic minority groups compared with White participants (22).

A recent CMS report noted that disparities in clinical care among Hispanic and non-Hispanic White populations varied greatly by geography, especially in rural areas (23). Although these geographic disparities were not related to stroke care, they may contribute to the wider variations in access to stroke care and survival across the states among Hispanic residents. A few studies also explored the differences in stroke outcomes between non-Hispanic White people and Hispanic, Asian American, and Chinese people (24–27). A study of participants with AIS over age 65 in the American Heart Association’s Get With The Guidelines–Stroke program found that non-Hispanic Black and Hispanic patients had higher adjusted 1-year all-cause rehospitalization than non-Hispanic White patients (24). A study conducted in Hawaii comparing potentially preventable 30-day readmissions after stroke found that Chinese patients may be at higher risk than non-Hispanic White patients (25). One Medicare study found that beneficiaries in hospitals with stroke certification had lower stroke mortality, regardless of the size of the hospital, than hospitals without certification (26). Another Get With The Guidelines–Stroke study with linked Medicare data showed that academic hospitals as compared with nonacademic hospitals and those in the Northeast or West compared with South or Midwest had more favorable stroke outcomes (27). The higher stroke risk profile, pre-stroke comorbidities, stroke severity, differences in access to health care after stroke, and stroke prevention programs may contribute to the wider variations in 5-year survival after AIS among minority groups across the states. In addition, minority beneficiaries may be underrepresented among Medicare FFS beneficiaries, which may contribute to the wider variation in 5-year stroke survival and limit the generalizability of our findings to minority beneficiaries (28,29).

Our study had limitations. First, because of the lack of measures of stroke severity, we were unable to examine its impact on overall survival. Second, AIS hospitalizations and deaths were based on administrative records and limited to Medicare FFS beneficiaries aged 66 or older. The first AIS hospitalizations identified in the MEDPAR database might not in fact be the first if the beneficiaries had a stroke before they enrolled in Medicare. Third, the AIS diagnosis was based on ICD-9-CM codes from claims data and was not clinically verified, which could lead to possible misclassification. Fourth, the wider variations in 5-year stroke survival rates observed among Hispanic people and people of other races/ethni-

cities may be due to the limited sample size for these groups. Lastly, the findings based on FFS beneficiaries in our study may not be generalizable to Medicare patients covered under a health maintenance organization (HMO) plan because of the possible differences in beneficiary characteristics between the 2 types of coverage plans.

Our findings demonstrated significant racial/ethnic and geographic differences in long-term survival after AIS. The variations across states in different racial/ethnic groups call for further study addressing disparities in treatment and access to health care, especially among minority groups. Stroke outcomes could be improved through public health and clinical strategies, such as awareness of risk factors, early diagnosis, and aggressive management of risk factors. Further research may explain the reasons for the significant geographic variations in survival after AIS and help develop prevention strategies to reduce these gaps across the states.

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## Author Information

Corresponding author: Xin Tong, Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy, MS–S107-1, Atlanta, GA 30341. Telephone: 770-488-4551. Email: xtong@cdc.gov.

Author Affiliations: <sup>1</sup>Division for Heart Disease and Stroke Prevention, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia.

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Tables

**Table 1. Characteristics of Medicare Fee-for-Service Beneficiaries Aged ≥66 Admitted to Hospital With Acute Ischemic Stroke, Medicare Cohort 2008–2017<sup>a</sup>**

Variable	Overall	Non-Hispanic White	Non-Hispanic Black	Hispanic	Other <sup>b</sup>
<b>Total</b>	1,019,267 (100.0)	856,648 (84.0)	94,001 (9.2)	43,278 (4.2)	25,340 (2.5)
<b>Age, y, median (IQR)</b>	79.9 (73.5–85.8)	80.2 (73.9–86.1)	77.2 (71.4–83.9)	78.2 (72.3–84.1)	78.6 (72.6–84.6)
<b>Age, y</b>					
66–74	312,294 (30.6)	249,424 (29.1)	38,306 (40.8)	15,703 (36.3)	8,861 (35.0)
75–84	419,128 (41.1)	354,990 (41.4)	35,467 (37.7)	18,162 (42.0)	10,509 (41.5)
≥85	287,845 (28.2)	252,234 (29.4)	20,228 (21.5)	9,413 (21.8)	5,970 (23.6)
<b>Sex</b>					
Male	451,296 (44.3)	383,081 (44.7)	36,396 (38.7)	19,991 (46.2)	11,828 (46.7)
Female	567,971 (55.7)	473,567 (55.3)	57,605 (61.3)	23,287 (53.8)	13,512 (53.3)
<b>Socioeconomic status<sup>c</sup>, %</b>					
≤25	260,798 (25.6)	231,553 (27.0)	14,520 (15.4)	6,302 (14.6)	8,423 (33.2)
26–50	254,642 (25.0)	226,558 (26.4)	13,942 (14.8)	8,287 (19.1)	5,855 (23.1)
51–75	261,930 (25.7)	213,565 (24.9)	27,430 (29.2)	14,341 (33.1)	6,594 (26.0)
>75	241,897 (23.7)	184,972 (21.6)	38,109 (40.5)	14,348 (33.2)	4,468 (17.6)
<b>Charlson Comorbidity Index</b>					
0	254,247 (24.9)	224,783 (26.2)	15,891 (16.9)	8,055 (18.6)	5,518 (21.8)
1	246,124 (24.1)	209,321 (24.4)	20,220 (21.5)	10,631 (24.6)	5,952 (23.5)
2	225,019 (22.1)	189,608 (22.1)	20,541 (21.9)	9,201 (21.3)	5,669 (22.4)
3	151,140 (14.8)	121,737 (14.2)	17,620 (18.7)	7,633 (17.6)	4,150 (16.4)
≥4	142,737 (14.0)	111,199 (13.0)	19,729 (21.0)	7,758 (17.9)	4,051 (16.0)
<b>Death</b>	701,718 (68.8)	591,493 (69.0)	66,172 (70.4)	28,239 (65.3)	15,814 (62.4)

Abbreviation: IQR, interquartile range.

<sup>a</sup> Values are number (percentage) unless otherwise indicated.

<sup>b</sup> Other non-Hispanic races.

<sup>c</sup> Socioeconomic status was defined by percentage below poverty level in the county of beneficiary residence in 2008; higher quartiles indicated higher level of poverty.

**Table 2. Crude and Adjusted 5-Year Survival After Acute Ischemic Stroke Among Medicare Fee-for-Service Beneficiaries Aged ≥66, Medicare Cohort 2008–2017<sup>a</sup>**

Characteristic	Crude <sup>b</sup>	Adjusted Model 1 <sup>c</sup>	Adjusted Model 2 <sup>d</sup>
<b>Total<sup>e</sup></b>	43.7 (43.6–43.8)	44.1 (44.0–44.2)	44.0 (43.9–44.1)
<b>Age at acute ischemic stroke, y</b>			
66–74	64.2 (64.0–64.4)	64.7 (64.6–64.9)	63.7 (63.6–63.9)
75–84	45.6 (45.4–45.7)	45.8 (45.7–46.0)	45.4 (45.2–45.5)
≥85	18.9 (18.7–19.0)	19.3 (19.2–19.5)	20.7 (20.6–20.8)
<b>Sex</b>			
Men	46.9 (46.8–47.1)	44.0 (43.9–44.1)	44.2 (44.1–44.4)
Women	41.2 (41.1–41.3)	44.3 (44.2–44.4)	43.9 (43.7–44.0)
<b>Race/ethnicity</b>			
Non-Hispanic White	43.7 (43.6–43.8)	44.5 (44.4–44.6)	43.8 (43.7–43.9)
Non-Hispanic Black	41.4 (41.1–41.7)	40.1 (39.9–40.4)	43.6 (43.3–43.8)
Hispanic	46.3 (45.8–46.7)	44.5 (44.2–44.9)	46.6 (46.2–47.0)
Other non-Hispanic races	48.9 (48.3–49.5)	47.4 (46.9–48.0)	48.7 (48.3–49.2)
<b>Sex by race/ethnicity</b>			
<b>Men</b>			
Non-Hispanic White	47.2 (47.0–47.3)	44.6 (44.5–44.7)	44.3 (44.2–44.4)
Non-Hispanic Black	42.1 (41.6–42.6)	36.9 (36.5–37.3)	40.8 (40.4–41.2)
Hispanic	48.7 (48.0–49.4)	44.3 (43.7–44.9)	46.6 (46.1–47.1)
Other non-Hispanic races	51.6 (50.7–52.5)	47.4 (46.7–48.2)	48.9 (48.2–49.7)
<b>Women</b>			
Non-Hispanic White	40.9 (40.8–41.1)	44.4 (44.3–44.5)	43.4 (43.3–43.5)
Non-Hispanic Black	40.9 (40.5–41.3)	42.1 (41.7–42.4)	45.1 (44.8–45.4)
Hispanic	44.2 (43.5–44.8)	44.7 (44.2–45.3)	46.6 (46.1–47.1)
Other non-Hispanic races	46.5 (45.7–47.4)	47.5 (46.8–48.2)	48.6 (47.9–49.3)
<b>Socioeconomic status<sup>f</sup>, %</b>			
≤25	44.3 (44.1–44.5)	45.2 (45.0–45.4)	44.8 (44.7–45.0)
26–50	44.2 (44.0–44.4)	44.2 (44.0–44.3)	44.0 (43.9–44.2)
51–75	43.6 (43.4–43.8)	44.0 (43.9–44.2)	44.0 (43.9–44.2)
>75	42.8 (42.6–43.0)	43.1 (43.0–43.3)	43.2 (43.0–43.3)

<sup>a</sup> Values are percentage (95% CI).

<sup>b</sup> Crude survival was estimated by using Kaplan–Meier life table.

<sup>c</sup> Model 1 adjusted survivals were estimated using Cox proportional hazards analyses adjusting for age, sex, race and Hispanic ethnicity, socioeconomic status, and state.

<sup>d</sup> Model 2 includes Charlson Comorbidity Index (0, 1, 2, 3 and ≥4) in addition to the covariates in adjusted Model 1.

<sup>e</sup> The median follow-up time for all Medicare fee-for-service beneficiaries with acute ischemic stroke was 4.0 years with a total of 4.08 million person-years.

<sup>f</sup> Socioeconomic status was defined by percentage below poverty level in the county of beneficiary residence in 2008; higher quartiles indicated higher level of poverty.

**Table 3. Demographic Information and Adjusted 5-Year Survival After Acute Ischemic Stroke Among Medicare Fee-for-Service Beneficiaries by State, Medicare Cohort 2008–2017**

State	Overall 5-year Survival <sup>a</sup> , % (95% CI)	Non-Hispanic White		Non-Hispanic Black		Hispanic		Other <sup>b</sup>	
		% of Cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)	% of cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)	% of Cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)	% of Cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)
Alabama	40.8 (40.3–41.3)	83.1	40.8 (40.3–41.4)	16.1	38.2 (36.9–39.5)	0.3	39.7 (31.7–49.9)	0.5	43.4 (36.5–51.5)
Alaska	43.4 (41.3–45.7)	77.9	44.3 (41.9–46.8)	2.6	40.9 (29.1–57.4)	2.0	—	17.5	42.8 (37.8–48.4)
Arizona	45.5 (44.9–46.1)	89.1	45.6 (45.0–46.3)	1.9	48.6 (44.2–53.4)	5.9	45.0 (42.5–47.7)	3.1	46.3 (42.8–49.9)
Arkansas	40.8 (40.2–41.4)	90.1	40.8 (40.2–41.4)	8.6	37.7 (35.6–39.9)	0.5	44.0 (35.7–54.3)	0.8	40.9 (34.2–48.8)
California	44.8 (44.5–45.1)	69.2	44.3 (44.0–44.7)	6.2	42.8 (41.6–43.9)	14.1	47.9 (47.1–48.8)	10.5	50.7 (49.7–51.6)
Colorado	44.2 (43.4–45.0)	88.0	44.6 (43.8–45.5)	2.7	43.8 (38.9–49.3)	7.6	40.6 (37.8–43.6)	1.8	44.3 (38.6–50.8)
Connecticut	44.6 (44.0–45.2)	90.6	44.7 (44.0–45.3)	5.1	42.6 (39.7–45.6)	2.8	45.6 (41.7–49.8)	1.4	47.1 (41.8–53.1)
Delaware	44.7 (43.6–45.8)	83.6	44.3 (43.2–45.6)	13.6	43.3 (40.2–46.6)	1.1	37.9 (29.1–49.4)	1.7	62.4 (54.2–71.8)
District of Columbia	42.3 (40.7–44.0)	23.2	39.7 (36.4–43.2)	72.9	40.2 (38.1–42.3)	1.9	42.9 (31.9–57.8)	2.0	47.2 (36.5–61.1)
Florida	44.6 (44.3–44.9)	84.2	44.8 (44.5–45.1)	6.9	42.4 (41.3–43.6)	7.7	44.3 (43.2–45.4)	1.2	51.1 (48.5–53.8)
Georgia	42.4 (42.0–42.8)	80.0	42.4 (41.9–42.9)	18.4	40.0 (39.0–41.1)	0.8	44.3 (39.3–49.9)	0.8	45.9 (41.0–51.3)
Hawaii	40.5 (39.0–42.0)	26.8	43.8 (41.0–46.7)	1.0	45.4 (32.7–63.1)	5.8	45.0 (39.1–51.9)	66.4	42.3 (40.3–44.4)
Idaho	43.1 (41.9–44.4)	96.1	43.5 (42.2–44.7)	0.2	—	1.9	42.9 (34.4–53.4)	1.8	33.9 (26.3–43.6)
Illinois	45.5 (45.1–45.8)	83.8	45.5 (45.2–45.9)	11.3	43.4 (42.4–44.6)	3.3	48.7 (46.8–50.7)	1.6	47.1 (44.3–50.1)
Indiana	44.2 (43.8–44.7)	91.2	44.2 (43.7–44.6)	6.8	42.3 (40.6–44.2)	1.3	46.2 (42.4–50.4)	0.6	50.1 (44.3–56.5)
Iowa	47.3 (46.6–48.0)	97.4	47.3 (46.7–48.0)	1.3	45.2 (39.4–51.9)	0.6	42.4 (34.4–52.2)	0.7	42.9 (35.3–52.2)
Kansas	45.3 (44.6–45.9)	93.6	45.5 (44.8–46.2)	3.6	41.0 (37.5–44.9)	1.6	46.0 (40.9–51.7)	1.2	43.1 (37.0–50.1)
Kentucky	42.7 (42.2–43.3)	94.7	42.6 (42.1–43.1)	4.7	42.4 (39.9–45.0)	0.2	52.2 (41.5–65.7)	0.4	44.1 (35.5–54.7)
Louisiana	42.6 (42.0–43.1)	74.3	43.0 (42.3–43.6)	23.4	38.8 (37.6–40.1)	1.5	46.6 (42.1–51.5)	0.8	48.6 (42.2–56.1)
Maine	45.8 (44.9–46.8)	98.8	45.9 (45.0–46.9)	0.2	—	0.2	—	0.8	49.5 (38.2–64.0)
Maryland	44.5 (44.0–45.0)	75.1	44.2 (43.7–44.8)	21.3	42.7 (41.6–43.9)	1.3	52.0 (47.7–56.8)	2.4	51.0 (47.6–54.7)
Massachusetts	45.2 (44.7–45.7)	91.7	45.0 (44.5–45.5)	3.5	47.8 (45.0–50.7)	2.7	49.3 (46.3–52.6)	2.2	52.1 (48.7–55.8)
Michigan	45.3 (44.9–45.6)	85.4	45.1 (44.7–45.5)	12.1	44.1 (43.0–45.2)	1.2	45.9 (42.7–49.4)	1.3	47.9 (44.7–51.4)
Minnesota	47.4 (46.7–48.1)	96.9	47.6 (46.9–48.4)	1.2	37.3 (31.4–44.3)	0.5	45.5 (35.7–57.8)	1.4	44.5 (38.8–50.9)
Mississippi	42.1 (41.5–42.7)	75.7	42.0 (41.3–42.7)	23.3	39.1 (37.8–40.4)	0.3	55.6 (45.3–68.3)	0.6	51.1 (43.1–60.5)
Missouri	44.4 (43.9–44.9)	92.1	44.6 (44.1–45.1)	6.8	40.0 (38.2–42.0)	0.6	38.2 (32.4–45.0)	0.6	44.8 (38.6–52.0)
Montana	46.6 (45.3–47.9)	94.6	46.8 (45.5–48.1)	0.3	—	0.8	—	4.3	46.5 (40.5–53.4)
Nebraska	46.1 (45.2–47.1)	95.6	46.3 (45.4–47.3)	2.0	38.3 (32.2–45.7)	1.4	46.7 (39.1–55.9)	1.0	40.9 (32.0–52.4)
Nevada	42.3 (41.4–43.3)	82.6	41.9 (40.8–42.9)	6.3	43.3 (39.4–47.6)	6.1	44.5 (40.5–48.9)	5.0	50.9 (46.5–55.8)
New Hampshire	46.6 (45.5–47.6)	98.2	46.7 (45.6–47.8)	0.3	—	0.7	—	0.8	43.4 (32.7–57.6)
New Jersey	44.2 (43.8–44.6)	82.0	44.1 (43.7–44.5)	10.5	42.5 (41.2–43.8)	5.2	47.6 (45.8–49.4)	2.3	50.2 (47.5–53.1)
New Mexico	41.3 (40.2–42.3)	69.0	41.4 (40.2–42.7)	1.6	40.3 (32.3–50.3)	24.4	42.9 (40.7–45.2)	4.9	45.1 (40.2–50.5)

Abbreviation: —, insufficient data.

<sup>a</sup> Adjusted survivals were estimated by using Cox proportional hazards analyses adjusting for age, sex, race and Hispanic ethnicity, socioeconomic status, and Charlson Comorbidity Index.

<sup>b</sup> Other non-Hispanic races.

<sup>c</sup> Percentage of total acute ischemic stroke Medicare fee-for-service beneficiaries with acute ischemic stroke, from 2008 through 2012.

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(continued)

**Table 3. Demographic Information and Adjusted 5-Year Survival After Acute Ischemic Stroke Among Medicare Fee-for-Service Beneficiaries by State, Medicare Cohort 2008–2017**

State	Overall 5-year Survival <sup>a</sup> , % (95% CI)	Non-Hispanic White		Non-Hispanic Black		Hispanic		Other <sup>b</sup>	
		% of Cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)	% of cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)	% of Cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)	% of Cohort <sup>c</sup>	5-year Survival <sup>a</sup> , % (95% CI)
New York	44.5 (44.2–44.8)	80.5	44.3 (44.0–44.7)	10.1	42.9 (41.9–44.0)	5.9	47.4 (46.0–48.8)	3.5	49.0 (47.3–50.9)
North Carolina	42.4 (42.0–42.8)	81.2	42.3 (41.9–42.8)	16.8	40.2 (39.3–41.2)	0.6	43.5 (38.6–49.0)	1.4	46.5 (43.1–50.1)
North Dakota	49.1 (47.6–50.6)	97.7	49.3 (47.8–50.8)	0.0	—	0.2	—	2.0	41.4 (32.3–53.0)
Ohio	44.0 (43.6–44.3)	89.8	43.9 (43.6–44.3)	8.6	42.8 (41.5–44.2)	0.9	45.1 (41.3–49.2)	0.7	47.1 (42.8–51.9)
Oklahoma	42.4 (41.8–43.0)	86.9	42.7 (42.1–43.3)	4.4	41.8 (39.0–44.7)	1.2	44.8 (39.6–50.6)	7.5	42.1 (40.0–44.3)
Oregon	44.1 (43.3–44.9)	94.8	44.2 (43.4–45.0)	0.9	41.1 (33.7–50.1)	1.8	41.3 (35.8–47.8)	2.5	47.2 (42.1–53.0)
Pennsylvania	44.0 (43.6–44.3)	92.1	44.1 (43.7–44.4)	5.8	40.4 (39.0–42.0)	1.1	46.6 (43.3–50.2)	1.0	46.3 (42.7–50.2)
Rhode Island	42.6 (41.3–44.0)	92.3	42.4 (41.1–43.9)	2.4	46.3 (37.4–57.5)	3.6	48.3 (41.0–56.9)	1.8	46.1 (35.6–59.8)
South Carolina	43.2 (42.7–43.8)	80.3	43.6 (43.0–44.2)	18.7	39.5 (38.2–40.8)	0.5	43.0 (35.7–51.8)	0.5	42.8 (35.8–51.2)
South Dakota	48.6 (47.3–50.0)	95.4	48.8 (47.5–50.2)	0.3	—	0.3	—	4.0	45.3 (39.1–52.4)
Tennessee	42.0 (41.5–42.4)	89.2	41.9 (41.4–42.4)	9.9	40.2 (38.7–41.8)	0.4	45.6 (38.1–54.6)	0.5	42.9 (36.5–50.4)
Texas	43.2 (42.9–43.4)	74.8	43.3 (42.9–43.6)	8.8	39.7 (38.8–40.7)	14.0	45.1 (44.2–46.0)	1.7	49.8 (47.7–52.1)
Utah	42.3 (41.2–43.5)	94.5	42.5 (41.3–43.7)	0.4	—	3.1	42.0 (35.5–49.7)	2.0	41.8 (34.3–51.0)
Vermont	45.0 (43.4–46.7)	98.6	45.0 (43.4–46.6)	0.2	—	0.4	—	0.8	—
Virginia	43.3 (42.9–43.7)	81.0	43.3 (42.9–43.8)	16.0	40.6 (39.5–41.8)	0.9	48.5 (44.0–53.4)	2.1	46.6 (43.5–49.9)
Washington	44.6 (44.0–45.1)	90.6	44.7 (44.1–45.2)	2.0	43.2 (39.3–47.4)	2.1	50.6 (46.8–54.7)	5.3	44.6 (42.2–47.1)
West Virginia	42.8 (42.0–43.6)	97.1	42.7 (41.9–43.5)	2.2	43.7 (38.4–49.6)	0.2	—	0.4	46.7 (35.4–61.6)
Wisconsin	45.8 (45.3–46.4)	94.5	45.9 (45.4–46.5)	3.1	41.5 (38.3–45.0)	1.1	48.9 (43.7–54.7)	1.4	49.5 (44.8–54.8)
Wyoming	45.0 (43.2–46.9)	93.8	45.2 (43.3–47.2)	0.4	—	3.4	47.2 (37.8–59.1)	2.3	34.3 (24.0–49.1)

Abbreviation: —, insufficient data.

<sup>a</sup> Adjusted survivals were estimated by using Cox proportional hazards analyses adjusting for age, sex, race and Hispanic ethnicity, socioeconomic status, and Charlson Comorbidity Index.

<sup>b</sup> Other non-Hispanic races.

<sup>c</sup> Percentage of total acute ischemic stroke Medicare fee-for-service beneficiaries with acute ischemic stroke, from 2008 through 2012.

### GIS SNAPSHOTS

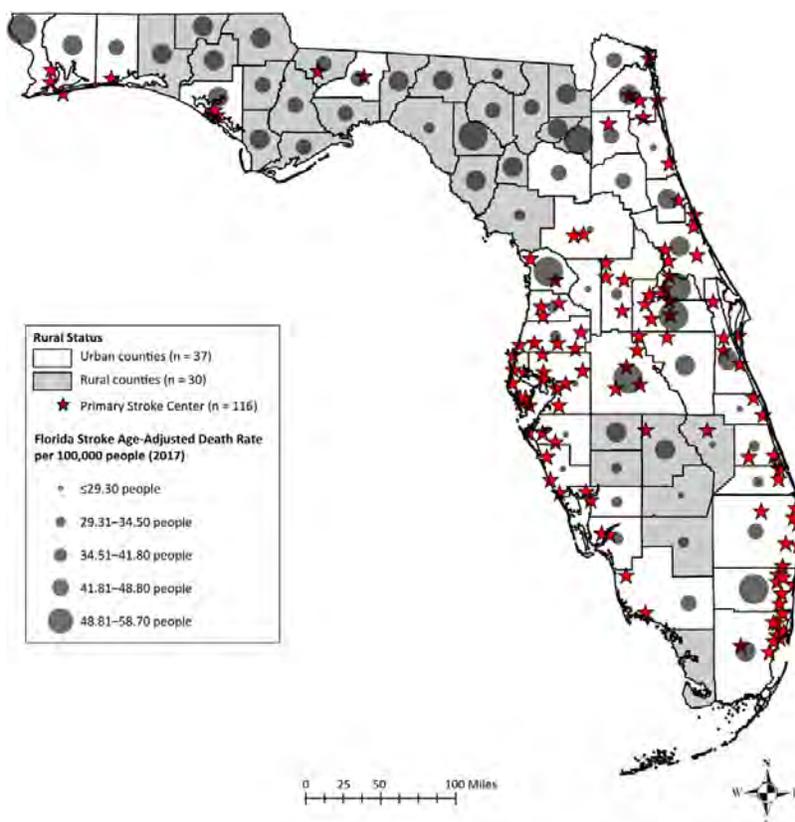
# Examining Stroke Disparities in Florida: Relationships Among County Classification, Age-Adjusted Stroke Mortality Rates, and the Presence of Primary Stroke Centers

Daudet Ilunga Tshiswaka, PhD<sup>1</sup>; Colleen Murphy, BSHS<sup>1</sup>; Guy-Lucien Whembolua, PhD<sup>2</sup>; Olajide Williams, MD<sup>3</sup>

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### PEER REVIEWED



Static display of Florida's distribution of rural versus urban and high versus low death rate, where stroke centers are in relation to urban versus rural and low versus high primary stroke centers, and age-adjusted stroke mortality rates, by quintile, in urban versus rural counties in 2017. Data sources: Florida's Geospatial Open Data Portal 2017, 2018; Rural Health Information Hub 2017; US Census Bureau, 2010; Florida Geographic Data Library, 2012.



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## Background

Although overall stroke mortality has declined in the United States for decades, recent data show that this decline in stroke deaths has slowed and that stroke remains 1 of the leading causes of death at the state level (1). In Florida, stroke is the fifth leading cause of death and was responsible for 12,602 deaths in 2017. Florida's death rate is 38.9 per 100,000 population and, in 2021, it is tied with Illinois at 20th place in stroke-related death rate rankings by state (2).

As part of an effort to improve the quality of care provided to stroke patients, primary stroke centers were created with a strict set of criteria for certifying hospitals that meet predefined standards (3) with the goal of stabilizing and providing emergency care for acute stroke patients (4). With these goals in mind, a patient is admitted to a primary stroke center or a comprehensive stroke center based on the severity of stroke symptoms. Although comprehensive stroke centers are equipped to provide care for complex stroke patients who often have more advanced therapeutic needs, primary stroke centers are equipped to provide care for less complex stroke patients and can administer acute stroke thrombolysis in a timely manner.

Having limited or no access to stroke centers remains a major challenge for many stroke patients. In the US, the scarcity of stroke centers is more pronounced in rural areas (5). In Florida, a rural county is a county with either 1) a population of 75,000 people or less, or 2) a population of less than 125,000 people and contiguous with a county that has a population of less than 75,000 people (6). By this definition, 30 out of the 67 counties in Florida are rural (7) and they contain 8.8% of Florida's population (8). Considering the importance of stroke centers, a gap exists in the literature assessing the relationship between county classification, age-adjusted stroke mortality rates, and the number of primary stroke centers in Florida.

The purpose of our research was to create maps that illustrate the relationship between age-adjusted stroke mortality rates and the presence of primary stroke centers in Florida. We hypothesized that stroke mortality will be higher in regions of Florida with fewer primary stroke centers.

## Data and Methods

We used publicly available age-adjusted stroke mortality data for 2017 from the Florida Department of Health Death Data Viewer (9). The 2017 primary stroke center shapefiles and the Florida county lines came from the Florida Geographic Data Library and

the ArcGIS Hub (7,10,11). The US Census Bureau website provided information about urban and rural counties as of 2010 (12). Independent variables were rural ( $n = 30$ ) and urban ( $n = 37$ ) county status, and dependent variables were number of primary stroke centers ( $n = 116$ ) and age-adjusted stroke mortality rates in Florida.

We geocoded primary stroke centers by using the Florida county lines shapefile as the basis for locating and indicating exact primary stroke centers onto the map (13). The Capital Regional Medical Center — Gadsden Memorial campus (in Gadsden County) was matched with zip code 32351 rather than 32353, as shown in the list of primary stroke centers. Bartow Regional Medical Center in Polk County was also changed from zip code 33831 to 33830. We used ArcMap 10.3 (ESRI) for geocoding and mapping purposes (13).

Point-biserial correlations were performed to determine the correlation between the urban county versus rural county status and age-adjusted stroke mortality rates. The test for normality (ie, Shapiro-Wilk test) suggested that age-adjusted stroke mortality rates were normally distributed throughout Florida's urban and rural counties ( $P > .05$ ). The number of primary stroke centers across Florida, however, was not normally distributed ( $P < .05$ ); therefore, we performed a nonparametric test (ie, Mann-Whitney  $U$  test) to consider the nonnormal distribution of urban county versus rural county primary stroke centers throughout Florida. More precisely, the Mann-Whitney  $U$  test was used to determine whether the number of primary stroke centers differed in urban and rural counties. All statistical analyses were performed using SPSS version 24 (IBM Corp).

## Highlights

Geocoding indicated that 116 primary stroke centers were primarily in the west, central, and east regions of the state. The point-biserial correlation coefficient for the relationship between urban counties versus rural counties and age-adjusted stroke mortality rates was  $r = 0.05$ , although the relationship was not significant ( $P = .67$ ). In the Mann-Whitney  $U$  test, the number of primary stroke centers in urban counties (mean = 47.8 centers,  $n = 37$  counties) was significantly higher than the number in rural counties (mean = 17.0 centers,  $n = 30$  counties) (Mann-Whitney  $U = 45$ ,  $P < .001$ .)

## Action

Analyzing the relationship between county classification, age-adjusted stroke mortality rates, and primary stroke centers has implications for stroke system development at the state level. Our

distribution map indicates a primary stroke center disparity in Florida, favoring urban counties with more primary stroke centers than rural counties. This finding underscores the need for more equitable resource allocation regarding primary stroke center availability in Florida.

The use of telemedicine for the treatment of stroke (ie, telestroke) may help reduce primary stroke center disparity by helping rural hospitals meet eligibility for certification as a hospital for treating acute stroke (14). Telestroke is a promising strategy for addressing the acute management of stroke patients, and barriers related to telestroke reimbursement have been addressed by passage of the Furthering Access to Stroke Telemedicine Act. Constraints to the use of telestroke, however, include the availability and affordability of technology, the need for ongoing technological support, logistical challenges related to the potential need for examination assistance by a participating bedside clinician or nurse, and several legal and ethical questions about provider credentials and patient safety and privacy (15,16).

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## Author Information

Corresponding Author: Daudet Ilunga Tshiswaka, PhD, University of West Florida, Department of Public Health, 11000 University Pkwy, Pensacola, FL 32514. Telephone: 850-474-2782. Email: daudeti@uwf.edu.

Author Affiliations: <sup>1</sup>University of West Florida, Department of Public Health, Pensacola, Florida. <sup>2</sup>University of Cincinnati, Department of Africana Studies, Cincinnati, Ohio. <sup>3</sup>Columbia University, Department of Neurology, New York, New York.

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## PROGRAM EVALUATION BRIEF

# Reducing Sodium Intake in Community Meals Programs: Evaluation of the Sodium Reduction in Communities Program, Arkansas, 2016–2019

Christopher R. Long, PhD<sup>1</sup>; Marissa J. Spear<sup>2</sup>; Cari A. Bogulski, PhD<sup>2</sup>; Brett Rowland, MA<sup>2</sup>; Krista Langston, MBA<sup>2</sup>; Bonnie Faitak, MA, MEd<sup>2</sup>; Karra Sparks, RD<sup>2</sup>; Pearl A. McElfish, PhD<sup>1</sup>

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## PEER REVIEWED

**Summary****What is known on this topic?**

High sodium intake is associated with hypertension and increased risk for cardiovascular disease, a leading cause of death for men and women in the United States.

**What does this report add?**

We evaluated a sodium-reduction intervention in community meals programs in northwest Arkansas and found substantial reductions in sodium served to diners after 3 years.

**What are the implications for public health practice?**

Sodium-reduction interventions in community meals programs, whose diners experience food insecurity, have low incomes, and are at high risk for hypertension, are effective and sustainable.

## Abstract

The Sodium Reduction in Communities Program (SRCP) aims to reduce dietary sodium intake through policy, systems, and environmental approaches. We evaluated progress of 3 years of SRCP activities in 3 community meals programs in northwest Arkansas. These activities sought to reduce dietary sodium intake through implementation of 1) food service guidelines, 2) procurement practices, 3) food preparation practices, and 4) environmental strategies. Mean reductions of 579 mg (–40%) in sodium served per diner and 525 mg (–22%) in sodium per 1,000 kcal served per

diner were found from baseline to Year 1. Mean reductions of 499 mg (–35%) in sodium served per diner and 372 mg (–16%) in sodium per 1,000 kcal served per diner were sustained from baseline to Year 3. These results highlight the effectiveness and sustainability of sodium reduction interventions in community meals programs, whose diners experience food insecurity, have low incomes, and are at high risk for hypertension.

## Introduction

The 2020–2025 *Dietary Guidelines for Americans* identify the daily recommended limit for sodium intake as 2,300 mg for people aged 14 years or older (1). Adults in the US consume a mean of 3,499 mg of sodium daily (2). High sodium intake is associated with hypertension and increased risk for cardiovascular disease (3–5), which is a leading cause of death for men and women in the US (6). Evidence demonstrates that lowering excessive sodium intake decreases hypertension (4,5) and is associated with lower morbidity and mortality rates from cardiovascular diseases (3–5).

The Centers for Disease Control and Prevention (CDC) launched the Sodium Reduction in Communities Program (SRCP) in 2010 with a goal to reduce sodium intake in US populations through policy, systems, and environmental approaches to increase access to and availability of lower-sodium products (7). Program sites provide help implementing sodium reduction strategies in food service venues that serve large populations, such as hospitals, worksites, schools, early care and education centers, and higher learning institutions. Each program site evaluates the outcomes in its venues.

The University of Arkansas for Medical Sciences (UAMS) was awarded a 5-year SRCP project in 2016 to implement sodium reduction strategies in several venues in northwest Arkansas, including community meals programs (ie, programs that offer free meals to low-income clients). These venues were selected because they serve northwest Arkansas communities at heightened risk for hy-



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pertension, particularly Marshallese and Hispanic or Latino populations experiencing low incomes and food insecurity (8–10).

UAMS engaged local stakeholders from Marshallese and Hispanic or Latino communities and from the local food system (ie, food vendors, community groups, and a culinary arts school) to determine which communities would be best served by applying for an SRCP award. These meetings clarified local SRCP priorities (eg, improving access to healthy foods for populations experiencing low incomes and food insecurity) and identified potential venues (eg, community meals). Engagement of the stakeholder group has been discussed previously (10,11).

Three community meals programs implemented the sodium reduction intervention and were the focus of this study. Each program served free midday meals for onsite consumption from 1 to 4 days per week. The programs served clients who experience challenges associated with food insecurity, housing insecurity, poverty, and unemployment (10). At baseline, each program served a mean of 235 meals per meal service. Combined, the 3 programs served a mean of 103,000 meals per year during the evaluation period.

## Purpose and Objectives

In our initial evaluation from baseline to Year 1 follow-up, community meals programs were combined with foods from weekend backpack nutrition programs intended for children. In that study, which provided an overview of initial activities and effectiveness across all venues (ie, schools, weekend backpack nutrition programs, and community meals), the combined programs reduced the mean sodium served per diner by 16.6% (10). The prior study provided an overview of initial activities and effectiveness across all venues (ie, schools, weekend backpack nutrition programs, and community meals). To examine the effects of sodium reduction strategies applied to a specific venue over time, this study was restricted to community meals and includes a second and third year of follow-up. Study aims were to evaluate initial sodium reduction for the community meals programs from baseline to Year 1 and to investigate the extent to which reductions were sustained in Years 2 and 3.

## Intervention Approach

The intervention approach included implementation of 4 broad strategies recommended by SRCP: 1) food service guidelines that discuss sodium, 2) procurement practices to reduce sodium content in food purchased, 3) food preparation practices to reduce sodium content, and 4) environmental strategies to encourage reduced sodium intake (eg, moving salt shakers from dining tables to the periphery of the dining area) (Table 1).

Representatives from each community meals program met 9 to 12 times per year from Years 1 to 3 with the UAMS team and participated in annual peer learning–exchange trainings in Years 1 to 3. The trainings were, in some instances, presented in collaboration with the Brightwater Center for the Study of Food or a University of Arkansas Culinary Nutrition instructor. Trainings often involved food preparation demonstrations (eg, knife skills training, fruit and vegetable preparation), lower-sodium product taste-testing, and feedback sharing between UAMS staff and community meals program staff.

All 3 programs implemented activities across the 4 strategies in Year 1; however, none of the programs implemented standardized purchasing lists (eg, commitments to prioritizing low-sodium or “no added salt” items when available from vendors) until Year 2. By Year 2, all 3 programs implemented all of the activities across the 4 strategies. Annually, UAMS staff supported each program’s staff to develop a comprehensive work plan to ensure sustainment of the strategies. For example, a UAMS registered dietitian continuously collaborated with community meals staff to create lower-sodium recipes by incorporating food items commonly donated by restaurants and grocery retailers (eg, adding low-fat milk or yogurt to donated salad dressings to lower sodium). Beginning in Year 2, UAMS’s registered dietitian worked with community meals staff to ensure reductions in sodium did not compromise energy intake for the programs’ food insecure diners. Each site sustained each activity through Year 3 and beyond.

## Evaluation Methods

Baseline data from the 3 community meals programs were collected between November 2016 and February 2017, before intervention implementation. Beginning in fall 2017, follow-up data were collected annually in October for Years 1, 2, and 3, attempting to minimize variability due to seasonal factors. At each program, baseline data were collected for all community meals served within a 4-week period, which included 4 to 12 meal services per program, depending on meal service frequency. At each program, annual follow-up data were collected for all community meals served within a 2- to 4-week period, which included 4 to 6 meal services per program, depending on meal service frequency. For each of the evaluated meals, data collected included the name, ingredients, and serving size of each menu item offered; the numbers of diners and of each menu item served; and sodium, energy, and other nutritional content of all food items distributed. Evaluators observed menus, ingredients, and serving sizes. Program staff provided numbers of diners and food items served.

These programs did not provide diners a choice of meals or serving sizes. In each program at any given meal service, every

diner was served the same food items and the same serving sizes. For this reason, within each program, sodium served per diner on a given day was equivalent to the milligrams of sodium per meal offered on that day. For each annual evaluation period, mean sodium served per diner was calculated for each program. This calculation was a weighted mean of each evaluated day's sodium served per diner weighted by the number of diners served on that day.

To evaluate potential unintended consequences of the sodium reduction strategies on energy content, means of energy served per diner were calculated for each program. These quantities were calculated similarly to the means for sodium content. To evaluate the changes in sodium served relative to the changes in energy, the mean number of milligrams of sodium per 1,000 kcal served per diner was calculated for each program. First, the mean number of milligrams of sodium per 1,000 kcal for each meal was calculated by computing the quotient of the milligrams of sodium served per diner divided by the calories served per diner and then multiplying the quotient by 1,000. This number was then multiplied by the number of diners served that meal. Next, this weighted number of milligrams of sodium per 1,000 kcal ratio was then summed across all of that program's meals in each data collection period and divided by the total number of diners served by that program across all meals in that data collection period.

Nutritional content was obtained from Nutrition Facts labels or from the Nutritionist Pro database (Axxya Systems, LLC). Nutritional content across all 4 data collection periods was calculated using Excel 2013 (Microsoft Corp), R (version 3.5.2; R Foundation for Statistical Computing), and RStudio (version 1.1.463; RStudio, Inc). This evaluation was determined to be exempt by the UAMS institutional review board.

## Results

Across the 3 programs, the mean amount of sodium served per diner from baseline to Year 1 follow-up decreased from 1,443 mg to 864 mg (−40%). The mean amount of sodium served per diner in Year 2 follow-up was 920 mg, which was more than the 864 mg observed in Year 1 follow-up (+6%) but less than baseline (−36%). In Year 3 follow-up, the mean amount of sodium served per diner was 944 mg, which was more than Year 2 but less than baseline (−35%) (Table 2).

The mean energy served per diner from baseline to Year 1 follow-up decreased from 621 kcal to 453 kcal (−27%). The mean energy served per diner in Year 2 follow-up was 586 kcal, which is more than the 453 kcal observed in Year 1 follow-up (+29%) but less than baseline (−6%). The mean energy served per diner in Year 3 follow-up was 479 kcal, which is less than Year 2 follow-up (−18%) and less than baseline (−23%) (Table 2).

The mean number of milligrams of sodium per 1,000 kcal served per diner from baseline to Year 1 follow-up decreased from 2,397 mg to 1,872 mg (−22%). The mean number of milligrams of sodium per 1,000 kcal served per diner in Year 2 follow-up was 1,571 mg, which is less than the 1,872 mg observed in Year 1 follow-up (−16%) and less than baseline (−34%). The mean number of milligrams of sodium per 1,000 kcal served per diner in Year 3 follow-up was 2,025 mg, which is more than Year 2 follow-up (+29%) but less than baseline (−16%) (Table 2).

Among the 3 programs, Program B demonstrated a noticeable reduction in amount of sodium served per diner from baseline to Year 1 from 1,310 mg to 313 mg (−76%). This reduction in sodium co-occurred with a reduction in mean energy served per diner from baseline to Year 1 follow-up from 691 kcal to 311 kcal (−55%). The amount of energy served per diner increased from Year 1 to Year 2 from 311 kcal to 517 kcal (+66%). The amount of energy served per diner then remained similar from Year 2 to Year 3, with Year 3 at 507 kcal (−2%). Mean number of milligrams of sodium per 1,000 kcal served per diner by Program B decreased from baseline to Year 1 (−44%) and then moved closer to baseline in Year 2 (−31% relative to baseline) and Year 3 (−6% relative to baseline).

## Implications for Public Health

The northwest Arkansas SRCP intervention in community meals programs reduced sodium served per diner and per meal and sustained reductions from Years 1 to 3. These results highlight the effectiveness and sustainability of sodium reduction interventions in community meals programs. The 3 community meals programs in this study ended Year 3 serving 944 mg of sodium per diner, which exceeds the 800 mg per meal recommended by CDC's *Smart Food Choices* guidelines for public facilities (12). The 3 programs ended Year 3 serving 2,025 mg of sodium per 1,000 kcal served, which exceeds the chronic disease risk reduction levels for sodium indicated in 2020–2025 *Dietary Guidelines for Americans* (ie, 2,300 mg of sodium per day for people aged 14 years or older) (1).

However, between baseline and Year 3, sodium served per diner dropped by 499 mg of sodium and number of milligrams of sodium per 1,000 kcal dropped by 372 mg. Daily sodium reductions of this magnitude achieved at the national level would result in significant savings in health care costs and significant gains in national productivity (13,14). Moreover, sodium reductions in community meals programs, many of whose diners face food insecurity, low incomes, and high risk for hypertension, may be particularly effective (8,9).

A key finding of this study is that sodium reduction was sustained throughout the evaluation period. In this study, levels of sodium served decreased sharply from baseline to Year 1 but began trending back toward baseline between Years 1 and 3. Challenges to sustaining the initial sodium reduction included turnover in staff at the meal programs and the gradual adjustments in the amount of energy served to mitigate the sharp drop in mean calories served per diner between baseline and Year 1. To sustain a meaningful reduction from baseline through Year 3, this intervention relied on durable policy, systems, and environment changes implemented during Years 1 and 2. Sustainability was further enhanced by evaluation efforts focused on process improvement. Each year, UAMS staff partnered with staff at each meal program to use evaluation results from their program to target the prior year's high-sodium items. This approach facilitated efficient use of program staff time to deploy new procurement and food preparation strategies to address the highest sodium items. In most cases, these strategies involved changes to recipes or ingredients rather than elimination of menu items.

One challenge of this intervention's process-focused evaluation approach is the time- and staff-intensive nature of data collection and analyses. This approach relied on technical expertise from registered dietitians, data collectors, and other UAMS staff, as well as close coordination with meal program staff. However, by assuming much of the evaluation effort, UAMS empowered meal program staff to focus their intervention-related effort on collaborating to develop strategies to address high-sodium items identified by the evaluation. The process-focused evaluation approach allowed UAMS and meal program staff to identify and address unintended consequences of the intervention, such as the Year 1 reduction of calories in meals served to food-insecure diners.

A limitation of this evaluation approach is that its time-intensive nature precluded data collection from nonintervention meal programs to use as comparison sites. Similarly, to conserve evaluator time and effort, the evaluation focused on sodium served rather than sodium consumed, and it did not incorporate consideration of food waste. Another limitation relates to the evaluation's attempt to minimize effects of seasonal variation by collecting each year's follow-up data in October. Although these 3 programs relied heavily on canned fruits and vegetables throughout the year, seasonal variations in availability of fresh foods may have resulted in differences in sodium served in community meals programs during the year. However, our findings build on evidence established by SRCP in other venues (15), reinforcing evidence of these interventions' effectiveness in reducing sodium across venues. Our study adds to the evidence base by showing that reductions in sodium served in community meals programs were sustained from Years 1

to 3. Ongoing evaluation of Years 4 and 5 will demonstrate the extent to which the reduction in sodium intake in community meals will be further sustained.

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## Author Information

Corresponding Author: Pearl A. McElfish, PhD, College of Medicine, University of Arkansas for Medical Sciences Northwest, Fayetteville, AR 72703. Telephone: 479-713-8000. Email: PAMcelfish@uams.edu.

Author Affiliations: <sup>1</sup>College of Medicine, University of Arkansas for Medical Sciences Northwest, Fayetteville, Arkansas. <sup>2</sup>Office of Community Health and Research, University of Arkansas for Medical Sciences Northwest, Fayetteville, Arkansas.

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Tables

**Table 1. Sodium Reduction Intervention Activities Implemented by 3 Community Meals Programs Participating in the Sodium Reduction in Communities Program, Arkansas, 2016–2019**

Intervention Strategy	Activities to Address Each Strategy
Food service guidelines that discuss sodium	<ul style="list-style-type: none"> <li>Implemented comprehensive food service guidelines that include sodium reduction standards and practices. Example: Adjusted donation requests to specify low- and lower-sodium products (eg, low-sodium or reduced-sodium canned corn)</li> </ul>
Procurement practices to reduce sodium content	<ul style="list-style-type: none"> <li>Implemented standardized purchasing lists with lower sodium items.<sup>a</sup> Example: Switched from purchasing canned to frozen vegetables (eg, frozen green beans).</li> <li>Participated in taste tests of lower-sodium ingredients for program staff. Example: Conducted taste tests with lower-sodium Thai chili sauce for grain bowls.</li> </ul>
Food preparation practices to reduce sodium content of menu items and meals	<ul style="list-style-type: none"> <li>Implemented policy to eliminate “free salting.” Example: Implemented policy for chefs to follow recipes for measuring salt rather than adding salt to taste.</li> <li>Developed and served recipes for lower-sodium menu items that incorporate donated foods. Example: Incorporated donated spinach into lasagna roll-up recipe.</li> <li>Implemented rinsing of canned vegetables to reduce sodium content. Example: Encouraged chefs to rinse canned vegetables (eg, black beans) with water.</li> </ul>
Environmental strategies that encourage reductions in dietary sodium intake	<ul style="list-style-type: none"> <li>Placed posters featuring sodium-reduction messages in food preparation areas. Example: “Shake the Habit” poster depicting spices with a message that reads “Shake the Salt Habit, Spice it Up!”</li> <li>Placed multilingual educational signs and dining table tents that address sodium reduction in dining areas. Example: “Eat More Color” table tents depicting tips for adding fruits and vegetables to meals in English, Spanish, and Marshallese.</li> <li>Received monthly newsletters of sodium-reduction tips sent by UAMS staff. Example: Suggested using onions, garlic, and vinegars in place of salt to add flavor to foods.</li> <li>Moved salt shakers away from dining tables to locations across the room. Example: Replaced salt shakers on dining tables with black pepper shakers.</li> </ul>

Abbreviations: UAMS, University of Arkansas for Medical Sciences.

<sup>a</sup> All 3 programs implemented each of the activities in Year 1 and sustained them throughout the evaluation period, with the exception of standardized purchasing lists, which were not implemented until Year 2.

**Table 2. Mean Diners, Energy, and Sodium Content, From Baseline Through Year 3, at 3 Community Meals Programs Participating in the Sodium Reduction in Communities Program, Arkansas, 2016–2019<sup>a</sup>**

Program/Variables	Baseline	Year 1	Year 2	Year 3
<b>Program A</b>				
Diners per meal service, n	261	246	273	292
Energy per diner, kcal	541	478	649	349
Sodium per diner, mg	1,403	1,067	1,050	748
Sodium per 1,000 kcal per diner, mg	2,661	2,220	1,665	2,151
<b>Program B</b>				
Diners per meal service, n	220	185	253	297
Energy per diner, kcal	691	311	517	507
Sodium per diner, mg	1,310	313	712	905
Sodium per 1,000 kcal per diner, mg	1,962	1,094	1,345	1,837
<b>Program C</b>				
Diners per meal service, n	202	195	225	270
Energy per diner, kcal	704	609	588	643
Sodium per diner, mg	2,034	1,262	1,033	1,329
Sodium per 1,000 kcal per diner, mg	2,798	2,323	1,779	2,131
<b>Overall<sup>b</sup></b>				
Diners per meal service, n	235	210	253	288
Energy per diner, kcal	621	453	586	479
Sodium per diner, mg	1,443	864	920	944
Sodium per 1,000 kcal per diner, mg	2,397	1,872	1,571	2,025

<sup>a</sup> Data were collected at each program immediately before intervention implementation and again in September or October for Years 1–3. Baseline data were collected during 4–12 consecutive days of service per program, and annual follow-up data were collected during 4–6 consecutive days of service per program. At baseline, none of the intervention activities had been implemented at any of the programs.

<sup>b</sup> Overall represents the combined data from Programs A, B, and C in each year.

## ORIGINAL RESEARCH

# COVID-19 Pandemic and Quality of Care and Outcomes of Acute Stroke Hospitalizations: the Paul Coverdell National Acute Stroke Program

Xin Tong, MPH<sup>1</sup>; Sallyann M. Coleman King, MD<sup>1,2</sup>; Ganesh Asaithambi, MD<sup>3</sup>; Erika Odom, PhD<sup>1,2</sup>; Quanhe Yang, PhD<sup>1</sup>; Xiaoping Yin, MS<sup>4</sup>; Robert K. Merritt, MS<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

Studies reported significant reduction in admissions for acute stroke during the COVID-19 pandemic, but only a few studies examined the changes in stroke quality of care.

**What is added by this report?**

Using data from a multistate stroke registry funded by the Centers for Disease Control and Prevention, we found that patients with more severe strokes were admitted during the COVID-19 pandemic than during the pre-pandemic period, and in-hospital death rates increased. However, the adherence to stroke quality of care measurements did not change.

**What are the implications for public health practice?**

Stroke is a life-threatening medical emergency; public health efforts should continue promoting awareness of stroke signs and symptoms and the urgency of seeking treatment of stroke despite the COVID-19 pandemic.

## Abstract

**Introduction**

Studies documented significant reductions in emergency department visits and hospitalizations for acute stroke during the COVID-19 pandemic. A limited number of studies assessed the adherence to stroke performance measures during the pandemic.

We examined rates of stroke hospitalization and adherence to stroke quality-of-care measures before and during the early phase of pandemic.

**Methods**

We identified hospitalizations with a clinical diagnosis of acute stroke or transient ischemic attack among 406 hospitals who contributed data to the Paul Coverdell National Acute Stroke Program. We used 10 performance measures to examine the effect of the pandemic on stroke quality of care. We compared data from 2 periods: pre-COVID-19 (week 11–24 in 2019) and COVID-19 (week 11–24 in 2020). We used  $\chi^2$  tests for differences in categorical variables and the Wilcoxon–Mann–Whitney rank test or Kruskal–Wallis test for continuous variables.

**Results**

We identified 64,461 hospitalizations. We observed a 20.2% reduction in stroke hospitalizations (from 35,851 to 28,610) from the pre-COVID-19 period to the COVID-19 period. Hospitalizations among patients aged 85 or older, women, and non-Hispanic White patients declined the most. A greater percentage of patients aged 18 to 64 were hospitalized with ischemic stroke during COVID-19 than during pre-COVID-19 (34.4% vs 32.5%,  $P < .001$ ). Stroke severity was higher during COVID-19 than during pre-COVID-19 for both hemorrhagic stroke and ischemic stroke, and in-hospital death among patients with ischemic stroke increased from 4.3% to 5.0% ( $P = .003$ ) during the study period. We found no differences in rates of receiving care across stroke type during the study period.

**Conclusion**

Despite a significant reduction in stroke hospitalizations, more severe stroke among hospitalized patients, and an increase in in-hospital death during the pandemic period, we found no differences in adherence to quality of stroke care measures.



The opinions expressed by authors contributing to this journal do not necessarily reflect the opinions of the U.S. Department of Health and Human Services, the Public Health Service, the Centers for Disease Control and Prevention, or the authors' affiliated institutions.

## Introduction

The US declared a national emergency in response to the COVID-19 pandemic on March 13, 2020 (1). At the same time, the Centers for Medicare and Medicaid Services (CMS) announced that patient hospitalization data from the first 6 months of 2020 would not be used in any hospital-based performance or payment programs, citing the need to focus on preparing for a potential surge of patients (2). Other quality improvement programs followed CMS recommendations (2). Since the start of the COVID-19 pandemic in the US, several studies have reported significant reductions in emergency department visits and hospitalizations for stroke (1,3–5). Stay-at-home orders, social distancing, and fear of contracting SARS-CoV-2 in health care settings might have contributed to these reductions (4,5). These reports are concerning given the established benefits of time-sensitive acute stroke treatments on long-term outcomes and lower 30-day mortality rates among patients treated in an integrated stroke care system (4). Despite multiple studies on the effect of the pandemic on stroke hospitalizations and treatment outcomes, only a few studies have assessed changes in quality of stroke care during the early phase of the COVID-19 pandemic. We used a multistate stroke registry to examine rates of stroke hospitalizations before and during the early phase of the COVID-19 pandemic as well as adherence to evidence-based performance measures for stroke hospitalizations during the pandemic.

## Methods

We used data from the Paul Coverdell National Acute Stroke Program (PCNASP), an ongoing quality improvement acute stroke program established by the Centers for Disease Control and Prevention (CDC) in 2001 to support state-based acute stroke quality-of-care registries (6). PCNASP collects de-identified data on stroke patients from participating hospitals in funded states. Case ascertainment for inclusion uses the final clinical diagnosis documented by the physician and considers the principal *International Classification of Diseases, 10th Revision, Clinical Modification* (ICD-10-CM) diagnosis codes (7). The final clinical diagnosis in PCNASP is determined by the patient's physician and abstracted from the medical record into the hospital's electronic data collection system. The case ascertainment and inclusion criteria for PCNASP performance measures and other analyses are based on the final clinical diagnosis only. Hospital participation in this program is voluntary. Trained abstractors used standard data definitions provided by CDC to collect detailed information on hospitalizations for stroke or transient ischemic attack (TIA) concurrent with or soon after hospitalization discharge.

We included data recorded in PCNASP on hospitalizations at 406 participating hospitals in 9 states from March 10 to June 15 in 2019 (pre-COVID-19 period), and March 8 to June 13 in 2020 (COVID-19 period), which corresponded to weeks 11–24 in both years. PCNASP data are not currently publicly available, but researchers can submit project proposals using established protocols, and CDC analysts generate data in tabular format ([www.cdc.gov/dhbsp/programs/stroke\\_registry.htm](http://www.cdc.gov/dhbsp/programs/stroke_registry.htm)).

Hospitalizations selected for the study period were for patients who had a clinical diagnosis of hemorrhagic stroke, including both intracerebral hemorrhage and subarachnoid hemorrhage; ischemic stroke; or TIA. We estimated the percentage reduction in hospitalizations for stroke and TIA from the pre-COVID-19 period to the COVID-19 period by age, sex, and race/ethnicity (by dividing the difference between the pre-COVID-19 and the COVID-19 periods by pre-COVID-19 hospitalizations and multiplying by 100). We used bootstrap resamples to determine 95% CIs on reduction percentages with 1,000 bootstrap resamples.

To quantify, monitor, and assess the quality of acute stroke care received, CDC in collaboration with the American Heart Association and the Joint Commission, developed 10 evidence-based performance measures (8). A patient who receives stroke care that meets all performance measures for which they are eligible is defined as receiving defect-free care (9). We examined the rates of adherence to these 10 evidence-based performance measures for acute stroke care and the percentage of patients who received defect-free care.

Demographic information collected for each hospitalized patient included age group (18–64, 65–74, 75–84, and ≥85 years), sex, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and other race (Asian, American Indian/Alaskan Native, Native Hawaiian/Other Pacific Islander, and unknown)), and insurance type. Baseline clinical characteristics included 1) stroke severity upon presentation as defined by the National Institutes of Health Stroke Scale (NIHSS) score; 2) stroke onset time, defined as the time the patient was last known to be well, before the beginning of the stroke; 3) use of emergency medical services; and 4) history of hypertension, hypercholesterolemia, diabetes, myocardial infarction or coronary artery disease, atrial fibrillation, heart failure, or current tobacco use. Among patients with ischemic stroke treated with reperfusion treatments, we examined the rates of intravenous thrombolysis (IVT) and intra-arterial treatment (IAT) administered. Outcomes assessed were rates of discharge to home, in-hospital death, and hemorrhagic complications after reperfusion treatment.

We used the  $\chi^2$  test to test for differences in distribution by demographic characteristics, clinical factors, and outcomes between the

pre-COVID-19 period and the COVID-19 period. We compared continuous variables using the Wilcoxon–Mann–Whitney rank test or the Kruskal–Wallis test. To account for multiple hypothesis testing, we calculated the false-discovery rate (denoting significance by a threshold of 5%) and reported the false-discovery rate–adjusted *P* values by stroke type (10). We performed all analyses by using SAS version 9.4 (SAS Institute Inc). This study was reviewed and approved by the CDC institutional review board.

## Results

During the study period, the PCNASP identified 64,461 hospitalizations with a clinical diagnosis of hemorrhagic stroke, ischemic stroke, or TIA. From the pre-COVID-19 period to the COVID-19 period, we found an overall reduction in stroke hospitalizations of 20.2% (95% CI, 18.9%–21.3%) (Table 1) and a reduction in the number of stroke admissions from 35,851 to 28,610 (Table 2). Of reductions in the 3 types of stroke hospitalizations, the reduction among TIA hospitalizations was the largest (41.8%; 95% CI, 38.8%–44.8%), followed by ischemic stroke (18.8%; 95% CI, 17.3%–20.3%) and hemorrhagic stroke (12.4%; 95% CI, 9.0%–15.8%). For hemorrhagic stroke and ischemic stroke, but not TIA, the magnitude of reduction increased with age. Reductions in stroke hospitalization rates were greater among women than among men. By race/ethnicity, the reduction was greatest among non-Hispanic White patients and least among Hispanic patients (Table 1).

Among ischemic stroke hospitalizations, the overall percentage of patients aged 18 to 64 years significantly increased during the study period, from 32.5% to 34.4% ( $P < .001$ ) (Table 2). The percentage of patients arriving to the hospital by emergency medical services significantly increased for TIA and ischemic stroke during the study period ( $P < .001$  for both) but was stable for hemorrhagic stroke ( $P = .82$ ). Overall, the median time from stroke onset to emergency department arrival increased significantly during the study period ( $P < .001$ ). The median NIHSS score at presentation was significantly higher during the COVID-19 period than the pre-COVID-19 period for hemorrhagic stroke and ischemic stroke, but not for TIA. We found no significant differences in medical comorbidities between the 2 periods except for hypertension and atrial fibrillation among ischemic stroke hospitalizations.

We found no differences in adherence to performance of stroke care measures among hemorrhagic stroke, ischemic stroke, and TIA hospitalizations from the pre-COVID-19 period to COVID-19 period (Table 3). Rates of defect-free care did not differ significantly by stroke type (hemorrhagic stroke,  $P = .56$ ; ischemic stroke,  $P = .83$ ; TIA,  $P = .79$ ).

The overall percentage of any reperfusion treatment among ischemic stroke patients was similar during the pre-COVID-19 and COVID-19 periods (17.0% vs 17.7%  $P = .12$ ) (Table 3). However, the percentage of IVT administered decreased from 55.7% during the pre-COVID-19 period to 50.6% during the COVID-19 period ( $P < .001$ ). The percentage of IAT significantly increased from 34.1% during the pre-COVID-19 period to 39.8% during the COVID-19 period ( $P < .001$ ). The rate of any hemorrhagic complications associated with reperfusion treatments did not change (4.0% to 4.5%;  $P = .54$ ). We found no differences in time from stroke onset to emergency department arrival ( $P = .54$ ), stroke onset to IVT administered ( $P = .22$ ), or emergency department arrival to IVT administered ( $P = .94$ ) from the pre-COVID-19 period to the COVID-19 period. The median time between emergency department arrival time and IAT administered time was 92 minutes during the pre-COVID-19 period and 96 minutes during the COVID-19 period ( $P = .12$ ). The percentage of ischemic patients who received IVT within 60 minutes and within 45 minutes ( $P = .95$  and  $P = .96$ , respectively) were not significantly different between the 2 periods (Table 3).

The percentage of patients who were discharged to home did not differ significantly between the 2 periods for patients with hemorrhagic stroke ( $P = .86$ ) or TIA ( $P = .47$ ), but a significantly higher proportion of patients with ischemic stroke were discharged to home during the COVID-19 period than during the pre-COVID-19 period (50.9% vs 49.7%;  $P = .04$ ). The rate of in-hospital death was significantly higher during the COVID-19 period than during the pre-COVID-19 period for ischemic stroke hospitalizations (5.0% vs 4.3%,  $P = .003$ ).

## Discussion

We observed an overall reduction of 20.2% in stroke and TIA hospitalizations when we compared the pre-COVID-19 period and the early phase of the COVID-19 pandemic. The largest reduction was 41.8% for TIA, followed by ischemic stroke and hemorrhagic stroke. Hospitalization rates among stroke patients aged 85 or older, women, and non-Hispanic White patients declined the most during the pandemic. Despite changes in the volume of stroke hospitalizations and the need to focus hospital resources on the pandemic, the adherence to stroke quality of care measures did not change during the early phase of the COVID-19 pandemic among PCNASP hospitals.

The reduction in stroke hospitalizations that we observed is consistent with several studies in the US and other countries (1,3–5,11–13). Strict instructions to stay at home, the practice of social distancing, and fears of infection in medical facilities may explain the decrease in stroke hospitalizations during the early

phase of the COVID-19 pandemic (12,13). Czeisler and colleagues estimated that 41% of US adults delayed or avoided medical care during the pandemic because of concerns about COVID-19 (14). Our study observed a reduction in stroke hospitalizations that increased with age, with patients aged 85 or older having the largest reduction in hospitalizations, at 25.9%. This observation is consistent with studies suggesting that older adults (aged  $\geq 65$ ), especially those living alone or with limited caregiver support, were more likely than younger adults to experience delays in stroke diagnosis and initiation of treatment during the COVID-19 pandemic (13,14).

TIA hospitalizations decreased by more than 40% from the pre-COVID-19 period to the COVID-19 period. This decrease may have been due to the reluctance of patients with mild stroke symptoms to seek hospital care, for fear of being exposed to COVID-19 (15). In addition, patients with minor stroke symptoms may not have sought care, or may have delayed seeking care, because of the social distancing mandates and stay-at-home orders implemented across the US (16). Without timely intervention and treatment, even for mild stroke symptoms, the risk of more severe outcomes or recurrent stroke increases (14,17,18). In our study, we found significantly higher median NIHSS scores among hospitalized stroke patients during the COVID-19 period, and the percentage of in-hospital deaths among patients with ischemic stroke significantly increased from 4.3% during the pre-COVID-19 period to 5.0% during the COVID-19 period. This finding was consistent with previous studies reporting that the decline in the number of patients admitted with mild strokes was far greater than was seen for moderate or severe strokes during the COVID-19 pandemic (17).

Rates of defect-free care in PCNASP-participating hospitals did not change during the study period across all stroke types. Specifically, the rate of stroke education delivery was not affected by the pandemic. Provision of stroke education to patients and caregivers is a critical performance measure. It provides the ideal transition from hospital to the next phase of care, and it has been shown to reduce the risk of recurrent stroke and decrease health costs for patients (9). In a recent publication, we reported that defect-free care significantly improved among patients with hemorrhagic stroke, ischemic stroke, and TIA from 2008 to 2018 among PCNASP-participating hospitals, reflecting the continuous efforts and the implementation of stroke quality improvement activities to improve the system of stroke care (9). The 10 performance measures endorsed by the American Heart Association, the Joint Commission, and CDC are essential in ensuring the quality of stroke care received by patients. Despite suspension of reporting requirements by CMS and other quality improvement programs at the beginning of the COVID-19 pandemic (2), PCNASP

as a federally funded quality program led by state health departments in collaboration with the American Heart Association and emergency medical service agencies continued its quality assessments during the COVID-19 pandemic.

Although the overall rates of any reperfusion therapies among patients with ischemic stroke did not change during our study period, the use of IAT only increased significantly, and the use of IVT only decreased significantly. This reduction in IVT was likely related to the longer median time between stroke onset and emergency department arrival found among patients with ischemic stroke. This finding is consistent with other findings that indicated a lower likelihood of IVT administration during the pandemic, suggesting that patients were arriving at the hospital too late to be eligible for receiving this treatment (19,20). However, among patients receiving IVT, the time between emergency department arrival and IVT administration did not change. This finding supports the evidence for efficiencies created in the emergency department despite the need to don and doff appropriate personal protective equipment during the COVID-19 pandemic (21). Given the larger time window of opportunity for being eligible for IAT (vs IVT), we were not surprised to observe a higher rate of IAT use during the COVID-19 period than during the pre-COVID period, which is consistent with reports of increasing IAT use over time (22). Furthermore, studies reported that higher rates of large vessel occlusion with coexistent COVID-19 could increase the rate of IAT use among all ischemic stroke patients, particularly among younger patients (23,24). In our study, the frequency of hemorrhagic complications associated with reperfusion treatments did not change between the 2 study periods.

Our study has several limitations. First, PCNASP is a voluntary quality improvement program that includes hospitals from selected states; therefore, the results might not be generalizable to the US. Second, registry data did not include information on the presence or absence of COVID-19 coinfections for stroke hospitalizations; consequently, we are uncertain about how COVID-19 may have affected the outcomes during the pandemic. Third, we only included the hospitals participating in PCNASP in both study periods in 2019 (pre-COVID-19) and 2020 (COVID-19), which could have contributed to selection bias. Fourth, PCNASP uses final clinical diagnosis to determine stroke hospitalizations. Some patients with principal ICD-10-CM codes for stroke or TIA may not have been included in the registry. However, a study suggested that the concordance between ICD-10-CM codes and stroke clinical diagnosis was generally high in PCNASP, so misclassification would apply to a small number of patients (25). Finally, our study compared point prevalence data (pre-COVID-19 period in 2019 vs the early phase of the COVID-19 pandemic period in 2020); it did not examine the potential effects of long-term trends in stroke hos-

pitalizations and quality of care because of the changes in the participating hospitals in PCNASP over time. The strengths of our study include the large volume of hospitalizations from different kinds of hospitals (rural, urban, academic, nonacademic) collected during the regular delivery of stroke care and information on stroke treatments and quality of stroke care measures from multiple states.

In summary, the rate of hospitalizations was higher among younger (aged 18–64 y) stroke patients and patients with more severe clinical conditions during the early phase of the COVID-19 pandemic than during the year before. We also observed a significant reduction in the percentage of stroke hospitalizations and an increase in overall in-hospital death from the pre-COVID-19 period to the early phase of the COVID-19 period. However, adherence to stroke quality measures and defect-free care did not change from the pre-COVID-19 period to the early phase of the COVID-19 pandemic among the hospitals participating in PCNASP.

The finding of adherence to stroke quality measures during the pandemic may be attributed to state health departments' continued outreach to the participating hospitals and their sharing of successes and strategies in well-formed stroke system-of-care partnerships. The dissemination of these strategies and experiences may support efforts to improve the system of care and promote processes that can withstand the impact of the pandemic. Finally, these findings indicate the importance of strengthening public health efforts that promote the awareness of stroke signs and symptoms and the urgency for seeking treatment of stroke, even for mild stroke symptoms.

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## Author Information

Corresponding Author: Xin Tong, MPH, Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy, MS S107-1, Atlanta, GA 30341. Telephone: 770-488-4551. Email: xtong@cdc.gov.

Author Affiliations: <sup>1</sup>Division for Heart Disease and Stroke Prevention, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia. <sup>2</sup>US Public Health Service, Atlanta, Georgia. <sup>3</sup>United Hospital, Allina Health, St Paul, Minnesota. <sup>4</sup>AllianceGroup, Inc, Atlanta, Georgia.

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Tables

**Table 1. Percentage Reduction of Stroke Hospitalizations Among Participating Hospitals From Weeks 11–24 in 2019 to Weeks 11–24 in 2020, by Demographic Characteristics, Paul Coverdell National Acute Stroke Program<sup>a</sup>**

Characteristic	Percentage Reduction (95% CI)			
	All Stroke	Hemorrhagic Stroke	Ischemic Stroke	Transient Ischemic Attack
<b>Total</b>	20.2 (18.9 to 21.3)	12.4 (9.0 to 15.8)	18.8 (17.3 to 20.3)	41.8 (38.8 to 44.8)
<b>Age group, y</b>				
18–64	16.2 (14.0 to 18.3)	10.0 (4.7 to 14.8)	14.1 (11.5 to 16.9)	45.0 (39.2 to 50.4)
65–74	19.2 (16.6 to 21.6)	9.3 (2.7 to 16.7)	18.1 (16.6 to 21.6)	40.7 (34.5 to 47.0)
75–84	22.7 (20.2 to 25.1)	16.2 (8.8 to 22.9)	21.6 (20.2 to 25.1)	38.2 (31.2 to 44.1)
≥85	25.9 (23.1 to 28.9)	19.6 (11.2 to 27.6)	24.2 (20.8 to 27.1)	42.9 (35.6 to 49.4)
<b>Sex</b>				
Male	17.4 (15.5 to 19.2)	8.2 (3.1 to 13.0)	16.8 (14.7 to 18.9)	37.6 (32.8 to 42.6)
Female	23.0 (21.2 to 24.5)	16.4 (11.7 to 20.9)	20.9 (19.0 to 23.0)	45.2 (40.9 to 48.9)
<b>Race/ethnicity</b>				
Non-Hispanic White	22.3 (20.7 to 23.6)	16.4 (12.4 to 20.3)	20.7 (19.1 to 22.5)	41.2 (37.4 to 44.6)
Non-Hispanic Black	18.1 (15.1 to 21.0)	11.4 (2.9 to 19.4)	15.5 (11.7 to 19.0)	47.1 (39.7 to 53.5)
Hispanic	8.7 (2.5 to 14.9)	–2.9 (–18.0 to 10.9)	7.3 (0.1 to 14.2)	39.4 (26.5 to 51.9)
Other race <sup>b</sup>	15.3 (10.9 to 19.7)	3.0 (–7.5 to 13.2)	17.0 (10.8 to 22.1)	37.0 (23.5 to 48.4)

<sup>a</sup> Week 11 (March 10–16, 2019) to week 24 (June 9–15, 2019) defined as the pre-COVID-19 pandemic period and week 11 (March 8–14, 2020) to week 24 (June 7–13, 2020) as the COVID-19 pandemic weeks. Percentage reduction in number of stroke hospitalization between 2019 and 2020 is calculated as  $[(2019-2020)/(2019)] \times 100$ , and the bootstrap resamples were used to determine the 95% CI with 1,000 bootstrap resamples. Data source: Paul Coverdell National Acute Stroke Program.

<sup>b</sup> Includes Asian, American Indian/Alaska Native, Native Hawaiian/Other Pacific Islander, and unknown.

**Table 2. Demographic and Clinical Information of Acute Stroke Patients Admitted to Participating Hospitals From Weeks 11–24 in 2019 to Weeks 11–24 in 2020, Paul Coverdell National Acute Stroke Program<sup>a</sup>**

Variable	All Stroke			Hemorrhagic Stroke			Ischemic Stroke			Transient Ischemic Attack		
	2019	2020	<i>P</i> Value <sup>b</sup>	2019	2020	<i>P</i> Value <sup>b</sup>	2019	2020	<i>P</i> Value <sup>b</sup>	2019	2020	<i>P</i> Value <sup>b</sup>
<b>Total</b>	35,851	28,610	—	5,568	4,877	—	26,543	21,557	—	3,740	2,176	—
<b>Age, median (IQR), y</b>	71 (60–81)	70 (60–81)	<.001	68 (55–79)	67 (56–78)	.21	71 (61–82)	71 (60–81)	<.001	73 (62–82)	73 (63–82)	.69
<b>Age group, y</b>												
18–64	12,189 (34.0)	10,217 (35.7)	<.001	2,414 (43.4)	2,173 (44.6)	.41	8,636 (32.5)	7,418 (34.4)	<.001	1,139 (30.5)	626 (28.8)	.51
65–74	8,814 (24.6)	7,121 (24.9)	.45	1,253 (22.5)	1,136 (23.3)	.52	6,654 (25.1)	5,447 (25.3)	.72	907 (24.3)	538 (24.7)	.93
75–84	8,521 (23.8)	6,584 (23.0)	.04	1,177 (21.1)	986 (20.2)	.43	6,394 (24.1)	5,011 (23.2)	.047	950 (25.4)	587 (27.0)	.51
≥85	6,327 (17.6)	4,688 (16.4)	<.001	724 (13.0)	582 (11.9)	.21	4,859 (18.3)	3,681 (17.1)	<.001	744 (19.9)	425 (19.5)	.93
<b>Male sex</b>	17,857 (49.8)	14,746 (51.5)	<.001	2,693 (48.4)	2,473 (50.7)	.06	13,488 (50.8)	11,228 (52.1)	.01	1,676 (44.8)	1,045 (48.0)	.12
<b>Race/ethnicity</b>												
Non-Hispanic White	24,526 (68.4)	19,059 (66.6)	<.001	3,498 (62.8)	2,923 (59.9)	.01	18,370 (69.2)	14,573 (67.6)	<.001	2,658 (71.1)	1,563 (71.8)	.93
Non-Hispanic Black	6,063 (16.9)	4,964 (17.4)	.18	929 (16.7)	823 (16.9)	.82	4,508 (17.0)	3,810 (17.7)	.07	626 (16.7)	331 (15.2)	.43
Hispanic	1,977 (5.5)	1,805 (6.3)	<.001	411 (7.4)	423 (8.7)	.06	1,348 (5.1)	1,250 (5.8)	.001	218 (5.8)	132 (6.1)	.93
Other race <sup>c</sup>	3,285 (9.2)	2,782 (9.7)	.03	730 (13.1)	708 (14.5)	.12	2,317 (8.7)	1,924 (8.9)	.57	238 (6.4)	150 (6.9)	.80
<b>Health insurance</b>												
Medicaid	3,525 (9.8)	2,770 (9.7)	.61	745 (13.4)	633 (13.0)	.67	2,461 (9.3)	1,968 (9.1)	.72	319 (8.5)	169 (7.8)	.69
Medicare	22,886 (63.8)	17,003 (59.4)	<.001	3,052 (54.8)	2,556 (52.4)	.06	17,342 (65.3)	12,992 (60.3)	<.001	2,492 (66.6)	1,455 (66.9)	.93
Private	7,914 (22.1)	5,563 (19.4)	<.001	1,460 (26.2)	1,090 (22.3)	<.001	5,622 (21.2)	4,084 (18.9)	<.001	832 (22.2)	389 (17.9)	<.001
Self pay/no insurance	1,180 (3.3)	959 (3.4)	.75	251 (4.5)	217 (4.4)	.89	851 (3.2)	682 (3.2)	.85	78 (2.1)	60 (2.8)	.40
Not documented	346 (1.0)	2,315 (8.1)	<.001	60 (1.1)	381 (7.8)	<.001	267 (1.0)	1,831 (8.5)	<.001	19 (0.5)	103 (4.7)	<.001
<b>Time between last known to be well and emergency department arrival, median (IQR), h</b>	4.5 (1.4–11.9)	4.9 (1.7–12.8)	<.001	4.0 (1.4–9.2)	4.1 (1.6–9.6)	.58	5.1 (1.7–12.9)	5.6 (1.9–13.8)	<.001	2.3 (1.0–6.4)	2.3 (1.0–6.4)	.69
<b>Arrival at hospital by emergency medical services</b>	15,757 (44.0)	13,471 (47.1)	<.001	2,364 (42.5)	2,085 (42.8)	.82	11,720 (44.2)	10,268 (47.6)	<.001	1,673 (44.7)	1,118 (51.4)	<.001

Abbreviation: —, does not apply; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale.

<sup>a</sup> Week 11 (March 10–16, 2019) through week 24 (June 9–15, 2019) defined as the pre-COVID-19 pandemic period and week 11 (March 8–14, 2020) through week 24 (June 7–13, 2020) as the COVID-19 pandemic weeks. All values are number (percentage) unless otherwise indicated. Data source: Paul Coverdell National Acute Stroke Program.

<sup>b</sup> False discovery rate-adjusted *P* values at threshold of 5%.

<sup>c</sup> Includes Asian, Native Hawaiian/Other Pacific Islander, American Indian/Alaska Native, and unknown.

<sup>d</sup> NIHSS score ranges from 0 to 42; the higher the score, the greater the impairment.

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Variable	All Stroke			Hemorrhagic Stroke			Ischemic Stroke			Transient Ischemic Attack		
	2019	2020	<i>P</i> Value <sup>b</sup>	2019	2020	<i>P</i> Value <sup>b</sup>	2019	2020	<i>P</i> Value <sup>b</sup>	2019	2020	<i>P</i> Value <sup>b</sup>
<b>NIHSS score, median (IQR)<sup>d</sup></b>	3 (1–8)	4 (1–10)	<.001	7 (2–19)	9 (2–20)	<.001	3 (2–6)	4 (1–9)	<.001	1 (0–3)	1 (0–3)	.93
<b>NIHSS score<sup>d</sup></b>												
Missing	3,885 (10.8)	3,016 (10.5)	—	1,842 (33.1)	1,503 (30.8)	—	1,737 (6.5)	1,362 (6.3)	—	306 (8.2)	151 (6.9)	—
0–4	19,149 (53.4)	14,258 (49.8)	<.001	1,559 (28.0)	1,283 (26.3)	.14	14,652 (55.2)	11,257 (52.2)	<.001	2,938 (78.6)	1,718 (79.0)	.93
5–24	11,371 (31.7)	9,936 (34.7)	<.001	1,646 (29.6)	1,526 (31.3)	.14	9,238 (34.8)	8,108 (37.6)	<.001	487 (13.0)	302 (13.9)	.70
≥25	1,446 (4.0)	1,400 (4.9)	<.001	521 (9.4)	565 (11.6)	.001	916 (3.5)	830 (3.9)	.03	9 (0.2)	5 (0.2)	.93
<b>Medical history</b>												
Hypertension	27,136 (75.7)	21,311 (74.5)	<.001	3,907 (70.2)	3,352 (68.7)	.22	20,373 (76.8)	16,293 (75.6)	.005	2,856 (76.4)	1,666 (76.6)	.93
Hypercholesterolemia	17,835 (49.7)	14,271 (49.9)	.76	2,065 (37.1)	1,857 (38.1)	.49	13,733 (51.7)	11,175 (51.8)	.86	2,037 (54.5)	1,239 (56.9)	.30
Diabetes	11,908 (33.2)	9,464 (33.1)	.76	1,292 (23.2)	1,153 (23.6)	.70	9,348 (35.2)	7,576 (35.1)	.87	1,268 (33.9)	735 (33.8)	.93
Current smoker	6,288 (17.5)	5,004 (17.5)	.87	878 (15.8)	746 (15.3)	.64	4,963 (18.7)	4,003 (18.6)	.81	447 (12.0)	255 (11.7)	.93
Myocardial infarction/coronary artery disease	7,700 (21.5)	5,997 (21.0)	.16	855 (15.4)	735 (15.1)	.77	5,855 (22.4)	4,210 (21.8)	.30	909 (24.3)	540 (24.8)	.93
Atrial fibrillation	6,549 (18.3)	5,044 (17.6)	.05	822 (14.8)	752 (15.4)	.52	5,089 (19.2)	3,875 (18.0)	.002	638 (17.1)	417 (19.2)	.23
Heart failure	3,660 (10.2)	3,026 (10.6)	.17	423 (7.6)	389 (8.0)	.63	2,854 (10.8)	2,422 (11.2)	.13	383 (10.2)	215 (9.9)	.93

Abbreviation: —, does not apply; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale.

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<sup>b</sup> False discovery rate-adjusted *P* values at threshold of 5%.

<sup>c</sup> Includes Asian, Native Hawaiian/Other Pacific Islander, American Indian/Alaska Native, and unknown.

<sup>d</sup> NIHSS score ranges from 0 to 42; the higher the score, the greater the impairment.

**Table 3. Stroke Performance Measures, Treatments, and Outcomes, by Stroke Type Among Stroke Patients Admitted to Participating Hospitals From Weeks 11–24 in 2019 to Weeks 11–24 in 2020, Paul Coverdell National Acute Stroke Program<sup>a</sup>**

Factor	Hemorrhagic Stroke			Ischemic Stroke			Transient Ischemic Attack		
	2019	2020	P Value <sup>b</sup>	2019	2020	P Value <sup>b</sup>	2019	2020	P Value <sup>b</sup>
<b>Performance measures established by Paul Coverdell National Acute Stroke Program, %</b>									
STK-1: Venous thromboembolism prophylaxis	98.1	98.4	.56	97.5	97.5	.99	—	—	—
STK-2: Discharged on antithrombotic therapy	—	—	—	99.6	99.6	.83	98.0	98.5	.44
STK-3: Anticoagulation therapy for atrial fibrillation/flutter	—	—	—	98.0	97.7	.59	94.0	96.3	.39
STK-4: Arrival in 2 h and alteplase given in 3 h of last known to be well	—	—	—	94.3	93.5	.54	—	—	—
STK-5: Antithrombotic therapy by day 2	—	—	—	97.7	97.5	.54	98.1	97.4	.44
STK-6: Discharged on statin medication	—	—	—	98.7	98.6	.89	94.7	95.9	.39
STK-7: Dysphagia screening	84.3	85.2	.56	87.0	87.7	.12	—	—	—
STK-8: Stroke education	92.7	92.8	.93	95.3	95.3	.95	92.1	91.4	.50
STK-9: Smoking cessation counseling	97.9	98.1	.93	98.7	98.1	.23	95.7	95.7	.98
STK-10: Assessed for rehabilitation	98.7	99.0	.56	99.3	99.3	.83	—	—	—
Defect-free care	83.7	84.7	.56	81.8	82.0	.83	87.7	88.1	.79
<b>Treatment, %</b>									
Intravenous thrombolysis or intra-arterial reperfusion treatment	—	—	—	17.0	17.7	.12	—	—	—
Intravenous thrombolysis reperfusion treatment only	—	—	—	55.7	50.6	<.001	—	—	—
Intra-arterial reperfusion treatment only	—	—	—	34.1	39.8	<.001	—	—	—
Intravenous thrombolysis and intra-arterial reperfusion treatment	—	—	—	10.2	9.5	.55	—	—	—
Any complication after reperfusion therapy <sup>c</sup>	—	—	—	4.0	4.5	.54	—	—	—
<b>Among patients given intravenous thrombolysis reperfusion treatment</b>									
Time between last known to be well and emergency department arrival, median (IQR), min	—	—	—	68 (44–115)	70 (44–119)	.54	—	—	—
Time between last known to be well and intravenous thrombolysis administered, median (IQR), min	—	—	—	125 (89–174)	129 (89–178)	.22	—	—	—
Time between emergency department arrival and intravenous thrombolysis administered, median (IQR), min	—	—	—	49 (35–70)	50 (34–70)	.94	—	—	—
Time between emergency department arrival and intravenous thrombolysis administered ≤60 min, %	—	—	—	66.5	66.2	.95	—	—	—
Time between emergency department arrival and intravenous thrombolysis administered ≤45 min, %	—	—	—	43.6	43.4	.96	—	—	—

Abbreviation: —, does not apply; IQR, interquartile range; STK, stroke.

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<sup>b</sup> False discovery rate-adjusted *P* values at threshold of 5%.

<sup>c</sup> The complication of either symptomatic intracranial hemorrhage or life-threatening or serious systemic hemorrhage within 36 hours after treatment.

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Factor	Hemorrhagic Stroke			Ischemic Stroke			Transient Ischemic Attack		
	2019	2020	P Value <sup>b</sup>	2019	2020	P Value <sup>b</sup>	2019	2020	P Value <sup>b</sup>
<b>Among patients given intra-arterial reperfusion treatment</b>									
Time between emergency department arrival and intra-arterial treatment administered, median (IQR), min	—	—	—	92 (60–132)	96 (62–139)	.12	—	—	—
<b>Outcomes, %</b>									
Discharged to home	29.4	29.7	.86	49.7	50.9	.04	83.6	84.6	.47
Discharged to hospice	6.9	8.6	.02	4.2	5.0	<.001	0.7	0.6	.79
Discharged to acute care facility	3.3	3.1	.86	2.2	2.2	.95	0.6	1.0	.40
Discharged to another health care facility	39.4	36.6	.02	38.5	35.3	<.001	13.1	11.3	.25
In-hospital death	20.7	21.4	.56	4.3	5.0	.003	0.1	0.5	.08

Abbreviation: —, does not apply; IQR, interquartile range; STK, stroke.

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## ORIGINAL RESEARCH

# Differences in Blood Pressure Levels Among Children by Sociodemographic Status

Melissa Goulding, MS<sup>1</sup>; Robert Goldberg, PhD<sup>2</sup>; Stephenie C. Lemon, PhD<sup>1</sup>

Accessible Version: [www.cdc.gov/pcd/issues/2021/21\\_0058.htm](http://www.cdc.gov/pcd/issues/2021/21_0058.htm)

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## PEER REVIEWED

**Summary****What is already known on this topic?**

High blood pressure (BP) affects many US children; however, most prevalence estimates are based on outdated data and guidelines. Although studies have shown that childhood hypertensive BP is not evenly distributed across sociodemographic groups, they do not account for body weight as a contributor to prevalence disparities.

**What is added by this report?**

Our study provides contemporary national prevalence estimates of elevated and hypertensive BP among children across sociodemographic groups and examines the effect of weight on observed disparities.

**What are the implications for public health practice?**

Factors beyond inequalities in body weight may contribute to disparities in elevated BP among US children. Further investigation of these disparities is needed to inform targeted public health efforts.

## Abstract

**Introduction**

The American Academy of Pediatrics (AAP) updated its blood pressure (BP) screening guidelines in 2017 to emphasize body weight as a risk factor. We provide contemporary, nationally representative estimates of prevalence of elevated and hypertensive BP among US children and examine sociodemographic prevalence differences, accounting for the influence of weight.

**Methods**

We used cross-sectional data from children aged 8 to 17 years (N = 5,971; weighted N = 36,612,323) collected from 2011 through 2018 in 4 biennial cycles of the National Health and Nutrition Examination Survey (NHANES). Children's BP was categorized as

normal, elevated, or hypertensive. Sociodemographic characteristics included were sex, age, race/ethnicity, family income, and education. Log binomial regression, with and without adjustment for weight (dichotomized at the 85th body mass index percentile), determined prevalence estimates and differences for elevated and hypertensive BPs with 95% CIs.

**Results**

In NHANES data collected from 2011 through 2018, 7.2% (95% CI, 6.3%–8.3%) of US children had elevated BP, and 3.8% (95% CI, 3.3%–4.5%) had hypertensive BP according to 2017 AAP guidelines. Differences in prevalence of weight-adjusted elevated BP indicated higher prevalence among children aged 16 to 17 years compared with children aged 8 to 9 years (prevalence difference, +6.3%; 95% CI, 3.2%–9.4%), among males compared with females (+4.6%; 95% CI, 2.7%–6.4%), and among non-Latino Black children compared with non-Latino White children (+4.0%; 95% CI, 2.2%–5.8%). Crude hypertensive BP prevalence was highest among children aged 8 to 9 years, male children, and Mexican American children. The only difference remaining after weight adjustment was among children aged 8 to 9 years and 13 to 15 years.

**Conclusion**

Elevated BP was most prevalent among US children who were older, male, or non-Latino Black. Factors beyond inequalities in body weight may contribute to disparities in elevated BP.

## Introduction

Hypertension affected nearly 4% of US children from 2013 through 2016 (1). The high prevalence of childhood obesity has contributed to an increase in several chronic conditions among children, including hypertension (2). Children who are overweight have higher systolic and diastolic blood pressure (BP) (3) than normal-weight children, and those with obesity have a threefold higher risk of hypertension compared with children of healthy weight (4). Given the relationship between weight and BP, the American Academy of Pediatrics (AAP) changed its clinical practice guidelines in 2017 with new normative pediatric BP



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tables to assess children's BP percentiles and categories on the basis of healthy body weight, in contrast to their previous guidelines, which included children of all weight statuses (5). Prevalence estimates based on AAP's earlier guidelines may have been biased by body weight and therefore warrant reinvestigation. Although AAP's guideline changes increased estimated prevalence of hypertension among US children (from 1.9% to 3.5%) (1), national estimates beyond 2016 are unavailable (1,5,6).

Few studies have described sociodemographic factors associated with hypertension among US children. Although prevalence in those studies appears to be higher among males and among Black, Mexican American, and other Latino children (1,5,7–9), many of those studies were based on past AAP guidelines (10) and few investigated the extent to which disparities in BP could be explained by differences in weight (7,9). Furthermore, investigation of potential associations between hypertension and socioeconomic factors has been limited (11,12).

The objective of our study was to provide nationally representative prevalence estimates of elevated and hypertensive BP among US children according to 2017 AAP guidelines. We also examined sociodemographic differences in prevalence and explored the role of weight status in relationship to differences in BP levels.

## Methods

### Study design and database

Our cross-sectional study used nationally representative data from the National Health and Nutrition Examination Survey (NHANES) (13), which is collected biennially by the National Center for Health Statistics to provide data on the health status of community-dwelling US residents. NHANES collects sociodemographic, dietary, and general health information by survey and medical, dental, and laboratory data by physical examination. We used data from 2011–2018, which consists of 4 biennial cycles. Unweighted survey response rates ranged from 53.6% to 78.5% for our study sample. Additional adjustments to weighting procedures were used to reduce the potential effects of response bias resulting from a lower response rate in the 2017–2018 NHANES cycle (13). NHANES data collection is approved by the National Center for Health Statistics Research and Ethics Review Board. Participant and parental consent were obtained for children aged 13 years or older. Participant assent and parental consent were obtained for children aged 7 to 12 years.

### Study population

NHANES BP data comes from physical examinations (13). For our study we included children aged 8 to 17 years for whom data on BP, height, weight, race/ethnicity, and socioeconomic characteristics were available. We excluded children who were missing BP measurements ( $n = 338$ ), had fewer than 3 BP readings ( $n = 68$ ), were missing data on body mass index (BMI) (weight in kg/height in  $m^2$ ) ( $n = 32$ ), or were missing data on sociodemographic characteristics ( $n = 702$ ). The final sample included 5,971 children, weighted to represent 36,612,323 children. To provide biennial prevalence estimates of hypertensive and elevated BP, the sample was defined by NHANES cycle. We used the entire sample for prevalence estimates of various BP parameters and differences in these end points according to sociodemographic factors.

### Operational definition of pediatric elevated and hypertensive BP.

Although clinical diagnosis of hypertension requires BP measurement across at least 3 occasions, NHANES is limited to physical examination on 1 occasion. Therefore, 3 BP measurements taken on a single occasion were averaged for each child in accordance with AAP guidelines for clinicians and common practice in pediatric hypertension studies (1,5,7–9). NHANES BP measurement techniques have been described previously (13). For children aged 8 to 12 years, we used age, sex, and height to determine their BP percentile according to the 2017 AAP BP tables. BP percentiles (for children aged  $<13$  y) or average measurement (for children aged 13–17 y) were then used for categorization according to 2017 AAP guidelines. Elevated BP was defined as ranging from  $\geq 90$ th percentile to  $<95$ th percentile or 120/ $<80$  mm Hg to  $<95$ th percentile (whichever is lower) for children aged 8 to 12 years and 120/ $<80$  to 129/ $<80$  mm Hg for those aged 13 to 17 years. Hypertensive BP was defined as a BP percentile of  $\geq 95$  or an average BP of  $\geq 130/80$  mm Hg (whichever was lower) for children aged 8 to 12 years and  $\geq 130/80$  mm Hg for those aged 13 to 17 years.

**Body mass index percentile.** Children's standing height and weight were measured by trained professionals during the NHANES physical examination, and their BMI was calculated. Methods and equipment used for anthropometric measures have been described previously (14). We determined BMI percentiles according to the Centers for Disease Control and Prevention 2000 growth charts (15). Weight status was categorized by BMI percentile to represent healthy weight (BMI percentile  $<85$ ), overweight (BMI percentile  $\geq 85$  to  $<95$ ), and obesity (BMI percentile  $\geq 95$ ). For adjusted prevalence estimates, we dichotomized weight to indicate unhealthy weight status (BMI percentile  $\geq 85$ ).

**Sociodemographic factors associated with elevated and hypertensive BP.** Age at the time of the NHANES physical exam-

ination was determined by the child's date of birth and was stratified at 8 to 9 years, 10 to 12 years, 13 to 15 years, and 16 to 17 years. Sex was determined by self-report with options of male or female. We used the more inclusive NHANES race/ethnicity variable in which children who identified as Mexican American were coded as such, those who identified as Hispanic or Latino were coded as other Latino, and those who identified as non-Latino were coded according to self-reported race of White, Black, Asian, or other (American Indian or Alaska Native, Native Hawaiian or Pacific Islander, mixed race).

We used 2 proxy measures for socioeconomic status, family poverty income ratio (PIR) and parent/guardian education level. PIR was calculated by dividing family income by the Department of Health and Human Services' poverty guidelines and then categorized as low (PIR <1.3), medium (PIR  $\geq$ 1.3 and <3.5), and high (PIR  $\geq$ 3.5). This categorization was used to be consistent with past obesity-related research and because a PIR of <1.3 is often used to determine eligibility for federally funded programs, including the Supplemental Nutrition Assistance Program (16). Parent/guardian education level was measured as the highest education of the household reference person, who was the first person listed in the household aged 18 years or older who owned or rented the residence.

### Statistical analysis

We computed frequencies on our study sample. Because each of the continuous variables had nonnormal distributions (assessed via Shapiro–Wilk test), medians with interquartile range were calculated. Prevalence estimates of elevated and hypertensive BP were computed for the 2011–2018 period overall and by 4 biennial cycles. We estimated crude prevalence differences and weight status (BMI percentile  $\geq$ 85) adjusted prevalence differences with 95% CIs for elevated and hypertensive BP for each sociodemographic subgroup through log binomial regression with the identity link (17). Each sociodemographic factor was assessed separately. Models were then adjusted for weight status. Assessment of correlations between weight status and each sociodemographic variable suggested adjusted models were not collinear. All analyses were appropriately weighted and analyzed with examination sample weights and Taylor series linearization (13) accounting for the complex sampling design of NHANES.

## Results

**Characteristics of US children.** Among children aged 8 to 17 years in NHANES 2011–2018, nearly a third (31.1%) were aged 13 to 15 years (Table 1). About half were female (49.7%). More than half (55.4%) were non-Latino White. The next largest racial/eth-

nic group was Mexican American (14.1%). Over one-third (37.6%) had an unhealthy body weight index (BMI) ( $\geq$ 85 percentile).

**Prevalence of elevated and hypertensive BP.** In the most recent NHANES cycle, 2017–2018, the prevalence of elevated BP was 6.2% (95% CI, 4.2%–9.3%) (Table 2) and the prevalence of hypertensive BP was 3.9% (95% CI, 2.9%–5.3%). Prevalence of hypertensive BP overall from 2011–2018 was 3.8% (95% CI, 3.3%–4.5%).

**Elevated and hypertensive BP by child's weight status.** Both elevated and hypertensive BP were more prevalent in children categorized as overweight or as having obesity compared with children of healthy weight. For elevated BP among overweight children, the prevalence difference was +4.3% (95% CI, 1.8%–6.8%). For children with obesity, the prevalence difference for elevated BP was +7.8% (95% CI, 5.7%–9.9%). For hypertensive BP, the prevalence difference for overweight children was +1.9% (95% CI, 0.3%–3.5%), and for children with obesity, the prevalence difference was +6.4% (95% CI, 4.3%–8.6%) (Table 3). Children with BMIs within the range indicating obesity had a prevalence of hypertensive BP almost 4 times greater than those with healthy weight (8.6%; 95% CI, 6.9%–10.9%) versus 2.2% (95% CI, 1.7%–2.8%).

**Sociodemographic differences in elevated BP prevalence.** Prevalence of elevated BP differed across sociodemographic groups. Prevalence was higher among males (9.6%; 95% CI, 8.1%–11.2%) than among females (4.9%; 95% CI, 3.9%–6.1%), and the difference remained significant after adjustment for body weight status (adjusted prevalence difference, +4.6%; 95% CI, 2.8%–6.5%) (Table 3). Prevalence was also greater among older children (16–17 y vs 8–9 y) before adjustment (crude prevalence difference +6.9%; 95% CI, 3.7%–10.2%) and after adjustment (adjusted prevalence difference, +6.3%; 95% CI, 3.2%–9.4%). Children of non-Latino Asian descent had the lowest crude prevalence of elevated BP (4.6%; 95% CI, 2.9%–7.4%), followed by non-Latino White children (6.3%; 95% CI, 5.1%–7.9%), whereas non-Latino Black children had significantly greater prevalence (10.4%; 95% CI, 8.8%–12.1%), with the crude prevalence difference +4.0% (95% CI, 2.1%–5.9%) (Table 3). After adjustment for weight status, these prevalence differences remained: +4.0 (95% CI, 2.2%–5.8%) among non-Latino Black children compared with non-Latino White children. Elevated BP also appeared to have an inverse relationship with socioeconomic status: the highest prevalence estimates were observed among children of low-income families (8.4%; 95% CI, 7.3%–9.6%) or from a household with parent/guardian educational attainment of less than a high school diploma (8.0%; 95% CI, 6.5%–9.9%) in unadjusted estimates. These socioeconomic differences were attenuated, and significance re-

mained only when comparing those with the lowest parent/guardian education (<high school diploma) to those with the highest (college graduate or above) after adjustment for weight status (adjusted prevalence difference, +2.1%; 95% CI, 0%–4.3%).

**Sociodemographic differences in prevalence of hypertensive BP.** Prevalence of hypertensive BP also differed by sociodemographic groups as did crude and adjusted prevalence differences. Although the unadjusted prevalence estimates were higher among children in all racial/ethnic groups compared with non-Latino White children (unadjusted prevalence difference from +0.7% [95% CI, -1.2% to 2.6%] to +2.3 [95% CI -0.4% to 5.1%]), these differences were not significant (Table 3). The unadjusted prevalence of hypertensive BP was higher among male children (prevalence, +1.7%; 95% CI, 0.2%–3.2%) than female children, but this difference was no longer significant after adjustment for the differential distribution of weight status. The prevalence of hypertensive BP was lower among children aged 13 to 15 years compared with those aged 8 to 9 years (unadjusted prevalence difference, -4.1%; 95% CI, -5.9% to -2.3%), and these differences remained significant after adjustment for weight status (adjusted prevalence difference, -3.8%; 95% CI, -5.6% to -2.0%). No differences in hypertensive BP prevalence were seen across PIR levels or parent/guardian education levels.

## Discussion

Our study showed prevalence among children aged 8 to 17 years to be 7.2% for elevated BP and 3.8% for hypertensive BP according to 2017 AAP guidelines. Our findings also confirm the important relationship between body weight and BP among children aged 17 years or younger. Children who were classified as overweight or having obesity were more likely to have elevated or hypertensive BP than healthy-weight children. We identified associated sociodemographic differences and found that some, but not all, of these differences were attenuated after accounting for disparities in body weight (1,8,9). We found higher prevalence estimates of elevated BP in males, older children (16–17 y), non-Latino Black children, and children of lower socioeconomic status. After adjustment for weight status, elevated BP prevalence differences in age, sex, race/ethnicity, and parent/guardian education persisted in these groups. Hypertensive BP was highest among younger children (8–9 y), Mexican America children, and males.

The prevalence of elevated and hypertensive BP observed in our study is higher than previous estimates (7,8). These earlier estimates were based on previous guidelines where weight distribution skewed the normative tables resulting in higher BPs at lower percentiles and fewer children meeting the elevated and hypertensive percentiles (18). A previous study that used the 2017 AAP

guidelines found a declining trend in hypertensive BP prevalence among children aged 8 to 17 years in NHANES data when comparing data collected in 2005–2008 with data collected in 2013–2016 (1). Focusing on more recent data and not aggregating biennial cycles, we found the prevalence of elevated and hypertensive BP to fluctuate between the study years of 2011 and 2018. However, overlapping confidence intervals suggest these differences were probably due to chance. The prevalence of elevated and hypertensive BPs was highest in the NHANES 2011–2012 cycle and lowest in 2013–2014. Past declining trends may have been misleading by not including the 2011–2012 cycle. Our prevalence estimate of 3.8% suggests that hypertensive BP among children remains an important public health issue and that the Healthy People 2020 goal of reducing this prevalence to 3.2% has thus far not been achieved (19).

Our study confirmed results of previous studies that showed overweight and obesity to be major risk factors for high BP in children (2–5,7,9,20) and supports changes in the AAP guidelines to the use of BP tables based on children of healthy body weight. In our study, adjustment for weight resulted in the attenuation of prevalence differences in elevated and hypertensive BP across the sociodemographic groups examined, emphasizing the influence of weight on observed disparities in BP. Thus, future studies that examine sociodemographic differences in children's BP levels need to adjust for the child's weight in further stratified or multivariable adjusted regression analyses to more systematically examine differences across any strata under study.

Consistent with the published literature, our findings suggest that in unadjusted estimates male children, children with parent/guardian with lower levels of education, and children from families with low income levels experienced a greater burden of cardiovascular risk because of disproportionate rates of unhealthy body weight (21). Sex differences in physiologic parameters, such as total cholesterol levels, and health behaviors, such as physical activity levels, have previously been highlighted in relation to childhood obesity and could contribute to the higher unadjusted prevalence of hypertensive BP observed among males (21). Disparities in the built environment, which affect patterns of physical activity, and access to healthy foods at affordable prices are acknowledged risk factors for children of low socioeconomic status who are overweight and could contribute to the higher unadjusted prevalence of elevated BP observed in children with low levels of parent/guardian education or income (22,23). Thus, through various weight-related pathways and mediators, weight-related disparities may contribute to disparities in unadjusted prevalence of BP levels across the sociodemographic factors of sex, education, and family income.

The crude racial/ethnic prevalence differences detected in our study underscore the disproportionate burden of elevated BP and unhealthy weight in non-Latino Black communities (24,25). Numerous factors across socioecological levels have been noted to contribute to disproportionate obesity prevalence across racial/ethnic groups (24,25). Here again, we see that factors contributing to weight disparities may also contribute to BP-related disparities (23). Weight-related risk factors can be systematic and range from health care access to safety and opportunity (26). Beyond describing their existence, more action needs to be taken to disentangle and prevent the factors contributing to these disparities to achieve health equity.

In our study, racial/ethnic disparities in prevalence of elevated and hypertensive BP remained after adjusting for weight status. This indicates that factors other than body weight contribute to racial/ethnic disparities in children's BP and that other pathways to less than optimal BP levels may begin in childhood. One such pathway is psychosocial stress, which has been extensively studied in adult populations (27). Empirical investigation of pathways (obesity-related and other) to racial/ethnic disparities in elevated BP prevalence is warranted as are interventional and policy-based efforts designed to narrow these differences and lower children's risk of subsequent cardiovascular disease. Weight disparities did not fully explain observed differences in elevated BP prevalence by sex in our study. In adult populations, sex-related BP differences are well established (28), and our findings suggest that the pathways to these sex-related BP differences may begin in childhood.

The differences we found in prevalence estimates of elevated and hypertensive BP in relation to age may be due in part to increased BP variability among young children (29) and in the use of percentile-based definitions for children aged 8 to 12 years compared with static cutoffs for children aged 13 to 17 years (30). Additionally, prevalence differences detected across age groups could be due to changes in BP associated with puberty and to the intersection of these changes with age, sex, and race/ethnicity. Further understanding is needed about how levels of BP disorders differ, and long-term follow-up data on BP levels among children are needed.

Our study highlights opportunities for reduction of elevated and hypertensive BP levels among US children. Efforts focusing on increased equity in access to care through policy changes to combat obesity in racially/ethnically and socioeconomically diverse populations should be expanded. Specific focus and efforts directed at systematic change to improve social determinants of health are also needed. Efforts to understand the causes of racial/ethnic and socioeconomic disparities and to reduce them could have short- and long-term benefits through improvements in children's health

and long-term prevention into adulthood (31). Given the well-known tracking of BP into the adult years and the strong association between elevated BP and cardiovascular and other chronic diseases, particular focus on preventing the large number of males with elevated BP from progressing to hypertension is warranted (32). Further research and risk reduction approaches should be directed to expanding BP screening in national samples of young children to improve our understanding of childhood hypertensive BP and reduce the risk of chronic diseases associated with hypertension later in life. Clinicians should be aware of socioeconomic disparities and the role of overweight highlighted in our study.

Strengths of the present study come from its use of contemporary nationally representative data and current BP screening guidelines. Although assessing subgroup differences in children's elevated and hypertensive BP may be difficult because of low case counts, we were able to combine the 4 most recent NHANES data cycles to obtain contemporary estimates across sociodemographic groups. The data analyzed in our study were collected by trained professionals who used standardized methods under controlled conditions and with quality control measures. This is important because collecting accurate BP measurements among children can be challenging (5).

Our study also has limitations. Despite the strengths inherent in the use of NHANES data, the study was limited by the data collected in that survey. Although declining response rates are of concern, NHANES has taken steps to mitigate the potential for nonresponse bias (13). Blood pressure measurements were limited to a single occasion rather than a series on 3 occasions, as is necessary for clinical diagnosis. However, previous childhood hypertension studies also used readings from a single occasion, including those providing national prevalence estimates (1,5). No single measure accurately reflects socioeconomic status, and we were unable to evaluate food insecurity as a marker of socioeconomic status, or low birthweight as a potential confounder, because NHANES assesses these measures only in children aged 16 years or older. Data on other important, potentially confounding variables, including family history of hypertension, chronic kidney disease, and chronic sleep disturbance were not available.

Elevated and hypertensive BP affects US children disproportionately in various sociodemographic groups, and body weight influences these health disparities. The burden of this cardiovascular risk is higher in children who are male, non-Latino Black, or of low socioeconomic status. Age, sex, and race/ethnicity may influence BP independently of weight status. Efforts are needed to better understand and intervene on the mechanisms through which these factors interact with BP in children. Obesity and hyperten-

sion are preventable disorders that potentially cause lifelong harm. Continued and amplified efforts are needed related to elevated and hypertensive BP among children aimed at lowering the prevalence, decreasing disparities, and ultimately achieving health equity.

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## Author Information

Corresponding Author: Melissa Goulding, MS, Division of Preventive and Behavioral Medicine, Population and Quantitative Health Sciences, University of Massachusetts Medical School, 368 Plantation St, Worcester, MA 01605. Telephone: 508-856-4098. Email: [Melissa.Goulding@umassmed.edu](mailto:Melissa.Goulding@umassmed.edu).

Author Affiliations: <sup>1</sup>Division of Preventive and Behavioral Medicine, Department of Population and Quantitative Health Sciences, University of Massachusetts Medical School, Worcester, Massachusetts. <sup>2</sup>Division of Epidemiology, Department of Population and Quantitative Health Sciences, University of Massachusetts Medical School, Worcester, Massachusetts.

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## Tables

**Table 1. Characteristics of Noninstitutionalized US Children Aged 8 to 17 Years, National Health and Nutrition Examination Survey (NHANES) 2011–2018**

Characteristic	Children (Unweighted, N = 5,971; Weighted, N = 36,612,323) <sup>a</sup>
<b>Age, y</b>	
8–9	18.9
10–12	29.2
13–15	31.1
16–17	20.9
<b>Female</b>	49.7
<b>Race/ethnicity</b>	
Non-Latino White	55.4
Non-Latino Black	13.8
Mexican American	14.1
Other Latino	7.1
Non-Latino Asian	4.1
Other <sup>b</sup>	5.5
<b>Highest level parent/guardian education</b>	
≥College graduate	28.8
High school diploma/GED/some college	52.6
<High school diploma	18.5
<b>Family income<sup>c</sup></b>	
High	30.1
Medium	39.2
Low	30.7
<b>Weight status</b>	
BMI percentile, median (IQR)	73.3 (42.7–93.0)
Healthy weight (BMI percentile <85)	62.5
Overweight (BMI percentile ≥85 to <95)	17.0
Obesity (BMI percentile ≥95)	20.6

Abbreviation: BMI, body mass index; IQR, interquartile range.

<sup>a</sup> Values are weighted percentage unless otherwise indicated.

<sup>b</sup> Includes American Indian or Alaska Native, Native Hawaiian or Pacific Islander, and mixed race.

<sup>c</sup> Determined by family poverty income ratio (PIR): family income divided by Department of Health and Human Services poverty guidelines (specific to family size, year, and state of residence). High = PIR >3.5, medium = PIR ≥1.3, < 3.5; low = PIR <1.3.

**Table 2. Prevalence of Elevated and Hypertensive Blood Pressure<sup>a</sup> Among US Children Aged 8 to 17 Years (N = 36,612,323)<sup>b</sup>, by Biennial Cycle, National Health and Nutrition Examination Survey (NHANES) 2011–2018**

NHANES cycle	Elevated Blood Pressure Prevalence, % (95% CI)	Hypertensive Blood Pressure Prevalence %, (95% CI)
2011–2012	8.3 (6.4–10.7)	4.6 (3.5–6.1)
2013–2014	6.0 (4.6–8.0)	2.6 (1.7–3.8)
2015–2016	8.2 (6.6–10.3)	4.3 (2.9–6.3)
2017–2018	6.2 (4.2–9.3)	3.9 (2.9–5.3)

<sup>a</sup> Hypertensive and elevated blood pressure determined by 2017 American Academy of Pediatrics guidelines. Hypertensive: blood pressure percentile  $\geq 95$  or average blood pressure  $\geq 130/80$  mm Hg (whichever was lower) for children aged 8–12 years and  $\geq 130/80$  mm Hg for children aged  $\geq 13$  years. Elevated blood pressure:  $\geq 90$ th percentile to  $< 95$ th percentile or  $120/<80$  mm Hg to  $< 95$ th percentile (whichever is lower) for children aged 8–12 years and  $120/<80$  to  $129/<80$  mm Hg for children aged 13 to 17 years.

<sup>b</sup> Unweighted, N = 5,971.

**Table 3. Prevalence of Elevated and Hypertensive Blood Pressure<sup>a</sup> by Sociodemographic Characteristics, US Children Aged 8 to 17 Years (N = 36,612,323)<sup>b</sup>, National Health and Nutrition Examination Survey (NHANES) 2011–2018**

Characteristic	Elevated blood pressure			Hypertensive blood pressure		
	Prevalence, % (95% CI)	Crude Prevalence Difference (95% CI)	Prevalence Difference Adjusted for Overweight/Obesity, % (95% CI)	Prevalence, % (95% CI)	Crude Prevalence Difference (95% CI)	Prevalence Difference Adjusted for Overweight/Obesity, % (95% CI)
<b>BMI percentile<sup>c</sup></b>						
Healthy weight, <85	4.9 (4.1 to 5.9)	Reference	NA	2.2 (1.7 to 2.8)	Reference	NA
Overweight, ≥85 to <95	9.2 (7.1 to 12.0)	4.3 (1.8 to 6.8)		4.1 (2.7 to 6.1)	1.9 (0.3 to 3.5)	
Obesity, ≥95	12.7 (10.7 to 15.1)	7.8 (5.7 to 9.9)		8.6 (6.9 to 10.9)	6.4 (4.3 to 8.6)	
<b>Age, y</b>						
8–9	5.9 (4.4 to 8.0)	Reference	Reference	6.0 (4.6 to 8.0)	Reference	Reference
10–12	4.3 (3.2 to 6.0)	-1.6 (-3.6 to 0.5)	-1.7 (-3.6 to 0.3)	4.0 (3.0 to 5.3)	-2.1 (-4.1 to 0.02)	-1.5 (-3.6 to 0.7)
13–15	7.0 (5.6 to 8.8)	1.1 (-1.2 to 3.4)	0.7 (-1.5 to 2.8)	2.0 (1.4 to 2.8)	-4.1 (-5.9 to -2.3)	-3.8 (-5.6 to -2.0)
16–17	12.8 (10.4 to 15.8)	6.9 (3.7 to 10.2)	6.3 (3.2 to 9.4)	4.5 (3.2 to 6.3)	-1.6 (-3.9 to 0.8)	-1.4 (-3.6 to 0.7)
<b>Sex</b>						
Female	4.9 (3.9 to 6.1)	Reference	Reference	3.0 (2.2 to 4.1)	Reference	Reference
Male	9.6 (8.1 to 11.2)	4.6 (2.8 to 6.5)	4.6 (2.7 to 6.4)	4.7 (3.7 to 5.9)	1.7 (0.2 to 3.2)	1.3 (-0.2 to 2.8)
<b>Race/ethnicity</b>						
Non-Latino White	6.3 (5.1 to 7.9)	Reference	Reference	3.2 (2.4 to 4.3)	Reference	Reference
Non-Latino Black	10.4 (8.8 to 12.1)	4.0 (2.1 to 5.9)	4.0 (2.2 to 5.8)	4.4 (3.3 to 5.8)	1.2 (-0.3 to 2.7)	0.5 (-0.8 to 1.9)
Mexican American	8.4 (6.8 to 10.5)	2.1 (-0.1 to 4.3)	1.6 (-0.5 to 3.7)	5.2 (3.9 to 6.8)	2.0 (0.1 to 3.9)	1.3 (-0.4 to 2.9)
Other Latino <sup>d</sup>	8.0 (6.0 to 10.6)	1.7 (-0.9 to 4.3)	1.7 (-0.7 to 4.1)	3.9 (2.4 to 6.2)	0.7 (-1.2 to 2.6)	0.3 (-1.5 to 2.0)
Non-Latino Asian <sup>d</sup>	4.6 (2.9 to 7.4)	-1.7 (-4.5 to 1.0)	-0.2 (-2.8 to 2.5)	4.3 (2.8 to 6.4)	1.1 (-0.7 to 2.9)	1.5 (-0.2 to 3.1)
Other <sup>d,e</sup>	6.7 (4.2 to 10.7)	0.4 (-2.9 to 3.7)	0.2 (-2.7 to 3.1)	5.5 (3.5 to 8.6)	2.3 (-0.4 to 5.1)	1.9 (-0.6 to 4.4)
<b>Family education</b>						
≥College graduate	5.4 (4.0 to 7.4)	Reference	Reference	3.9 (2.7 to 5.5)	Reference	Reference
High school diploma/GED/some college	8.0 (6.8 to 9.4)	2.5 (0.6 to 4.5)	1.6 (-0.3 to 3.5)	3.8 (3.0 to 4.9)	-0.02 (-1.7 to 1.7)	-0.7 (-2.4 to 0.9)
<High school diploma	8.0 (6.5 to 9.9)	2.6 (0.4 to 4.8)	2.1 (0.0 to 4.3)	3.8 (2.8 to 5.2)	-0.06 (-1.8 to 1.7)	-0.5 (-2.3 to 1.3)
<b>Family income<sup>f</sup></b>						
High	5.8 (4.2 to 7.9)	Reference	Reference	3.1 (2.1 to 4.5)	Reference	Reference

Abbreviation: NA, not applicable.

<sup>a</sup> Hypertensive and elevated blood pressure determined by 2017 American Academy of Pediatrics guidelines. Hypertensive: blood pressure percentile ≥95 or average blood pressure ≥130/80 mm Hg (whichever was lower) for children aged 8–12 years and ≥130/80 mm Hg for children aged ≥ 13 years. Elevated blood pressure: ≥90th percentile to <95th percentile or 120/<80 mm Hg to <95th percentile (whichever is lower) for children aged 8–12 years and 120/<80 to 129/<80 mm Hg for children aged 13 to 17 years.

<sup>b</sup> Unweighted, N = 5,971.

<sup>c</sup> BMI (weight in kg/height in m<sup>2</sup>) as percentile according to the Centers for Disease Control and Prevention 2000 growth charts.

<sup>d</sup> Had fewer than 30 participants; therefore, did not meet NHANES reporting standards in the hypertensive category.

<sup>e</sup> Includes American Indian or Alaska Native, Native Hawaiian or Pacific Islander, and mixed race.

<sup>f</sup> Determined by family poverty income ratio; family income divided by Department of Health and Human Services poverty guidelines (specific to family size, year and state of residence). High PIR = >3.5, medium PIR = ≥1.3 to <3.5, low PIR = <1.3.

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(continued)

**Table 3. Prevalence of Elevated and Hypertensive Blood Pressure<sup>a</sup> by Sociodemographic Characteristics, US Children Aged 8 to 17 Years (N = 36,612,323)<sup>b</sup>, National Health and Nutrition Examination Survey (NHANES) 2011–2018**

Characteristic	Elevated blood pressure			Hypertensive blood pressure		
	Prevalence, % (95% CI)	Crude Prevalence Difference (95% CI)	Prevalence Difference Adjusted for Overweight/Obesity, % (95% CI)	Prevalence, % (95% CI)	Crude Prevalence Difference (95% CI)	Prevalence Difference Adjusted for Overweight/Obesity, % (95% CI)
Medium	7.8 (6.5 to 9.2)	2.0 (−0.3 to 4.2)	1.3 (−1.1 to 3.6)	4.0 (3.1 to 5.2)	0.9 (−0.7 to 2.6)	0.4 (−0.9 to 1.7)
Low	8.4 (7.3 to 9.6)	2.2 (0.4 to 4.0)	1.4 (−0.4 to 3.2)	4.6 (3.6 to 5.8)	1.4 (−0.2 to 3.0)	0.6 (−0.8 to 2.1)

Abbreviation: NA, not applicable.

<sup>a</sup> Hypertensive and elevated blood pressure determined by 2017 American Academy of Pediatrics guidelines. Hypertensive: blood pressure percentile  $\geq 95$  or average blood pressure  $\geq 130/80$  mm Hg (whichever was lower) for children aged 8–12 years and  $\geq 130/80$  mm Hg for children aged  $\geq 13$  years. Elevated blood pressure:  $\geq 90$ th percentile to  $< 95$ th percentile or  $120/<80$  mm Hg to  $< 95$ th percentile (whichever is lower) for children aged 8–12 years and  $120/<80$  to  $129/<80$  mm Hg for children aged 13 to 17 years.

<sup>b</sup> Unweighted, N = 5,971.

<sup>c</sup> BMI (weight in kg/height in  $m^2$ ) as percentile according to the Centers for Disease Control and Prevention 2000 growth charts.

<sup>d</sup> Had fewer than 30 participants; therefore, did not meet NHANES reporting standards in the hypertensive category.

<sup>e</sup> Includes American Indian or Alaska Native, Native Hawaiian or Pacific Islander, and mixed race.

<sup>f</sup> Determined by family poverty income ratio; family income divided by Department of Health and Human Services poverty guidelines (specific to family size, year and state of residence). High PIR =  $> 3.5$ , medium PIR =  $\geq 1.3$  to  $< 3.5$ , low PIR =  $< 1.3$ .

## ORIGINAL RESEARCH

# Infant Mortality and Maternal Risk Factors in Texas: Highlighting Zip Code Variations in 2 At-Risk Counties, 2011–2015

Meliha Salahuddin, PhD, MBBS<sup>1,2,3</sup>; Krystin J. Matthews, PhD, MPH<sup>2,3</sup>;  
Nagla Elerian, MS<sup>2</sup>; David L. Lakey, MD<sup>2</sup>; Divya A. Patel, PhD<sup>1,2,3</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

The infant mortality rate (IMR) in Texas is below the Healthy People 2020 objective; furthermore, stark differences in IMR exist within the state.

**What is added by this report?**

During 2011 through 2015 in 2 Texas counties, maternal sociodemographic and pregnancy-related characteristics were significantly associated with infant mortality. Wide zip code–level variations in the IMR and key maternal risk factors existed in both counties.

**What are the implications for public health practice?**

Findings from the study helped identify communities where potential scaling of effective interventions to improve pregnancy outcomes were needed and identify key strategies to address preconception and interconception health.

## Abstract

**Introduction**

Stark differences in the infant mortality rate (IMR) exist by geography in Texas. The Healthy Families initiative sought to understand how evidence-informed practices implemented in the community can improve pregnancy-related outcomes in 2 counties in Texas with a high prevalence of maternal chronic conditions. The objective of this study was to examine associations between maternal risk factors and infant deaths to inform strategies to improve outcomes.

**Methods**

Two counties with high prevalence of maternal chronic conditions were selected as Healthy Families sites: one with lower prenatal care usage than other counties in the state but an IMR lower than Texas, and the other with a higher IMR among minority racial and ethnic groups compared with other women in the county and Texas overall. Cohort-linked birth and infant death records from 2011 through 2015 provided by the Texas Department of State Health Services were analyzed by using logistic regression to examine associations of maternal sociodemographic and pregnancy risk factors with infant death. The data were mapped at the zip code level. Analyses were limited to births to women aged 15 to 49 years who resided in Texas from 2011 through 2015 (n = 1,942,899 births).

**Results**

The Texas IMR was 5.4 per 1,000 live births, compared with 4.6 and 7.5 per 1,000 live births for Hidalgo and Smith counties, respectively. Congenital malformations were the leading cause of infant death in both counties for infants born in 2015, which was similar to Texas overall. In both counties, maternal marital status, education, multiple gestation, and cesarean delivery were significantly associated with infant mortality. Wide zip code–level variations in IMR and maternal risk factors were observed in both counties.

**Conclusion**

Variations in IMR and key maternal risk factors observed at the zip code level helped drive local strategies to maximize outreach of services to disproportionately affected communities.

## Introduction

Although the infant mortality rate (IMR) in Texas has remained below the Healthy People 2020 objective of 6.0 per 1,000 live births (1) since 2012, wide variation in the IMR exists across zip



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code areas in the state, with some zip codes having as many as 20 deaths per 1,000 live births in 2011 through 2014 (2). Further, racial and ethnic minority disparities in the IMR persist in Texas, with the IMR being 2 times higher for non-Hispanic Black infants compared with that of non-Hispanic White or Hispanic infants (3).

The prevalence of chronic maternal health conditions, which are linked to poor pregnancy-related outcomes, is also increasing in Texas. Prepregnancy obesity, which leads to various complications during pregnancy, has increased about 30% in Texas since 2009, with Black and Hispanic women having the highest rates (3). Hypertension and diabetes are also increasing among mothers in Texas, with Black and Hispanic women having the highest rate for hypertension and diabetes, respectively (3).

Given the high prevalence of racial and ethnic minority disparities in infant mortality and associated maternal risk factors, there is growing urgency to move evidence-informed research to practice and policy. The Healthy Families initiative was launched in fall 2016 by the Texas Health and Human Services Commission (HHSC), the agency that administers Medicaid and other women's health programs, with the overall goal of understanding multilevel contextual factors influencing pregnancy outcomes in populations that have low access to state-funded prenatal care and poor maternal and infant health outcomes (4). The 4-year initiative was a unique partnership between a state agency, academic institutions, and 2 communities. The HHSC provided flexible funding to support identification, development, implementation, adaptation, and evaluation of evidence-informed practices to address community-identified gaps in pregnancy outcomes (4). As part of the Healthy Families evaluation, secondary data analyses using vital records data were conducted to drive strategies to focus on evidence-informed practices in the disproportionately affected communities in the 2 counties. The goals of the study were to 1) identify individual-level factors influencing the IMR in the 2 selected counties in Texas that participated in the Healthy Families initiative; 2) identify the leading causes for infant deaths in the 2 counties in comparison to Texas; and 3) describe zip code-level variation in the IMR and associated key maternal risk factors in the 2 counties. Findings from these analyses were integrated into the Healthy Families initiative to inform the planning, adaptation, and implementation of evidence-informed programs and strategies to address the IMR in the 2 project sites.

## Methods

### Healthy Families study setting

Texas HHSC selected 2 Texas counties, Hidalgo and Smith, based on county-level maternal and infant health indicators, as project sites for the Healthy Families initiative. Hidalgo County is in

South Texas along the US–Mexico border and has lower prenatal care usage than other counties in the state but an IMR lower than Texas. Smith County is southeast of Dallas and has a higher IMR among minority racial and ethnic groups compared with other women in the county and Texas overall. US Census data indicate that both counties have median household incomes below the state level (5). The percentage of the population living below federal poverty guidelines is 12.9% in Smith County and 26.9% in Hidalgo county. The framework for the Healthy Families initiative and additional details about the 2 project sites have been described previously (4).

We conducted a cross-sectional secondary data analysis of cohort-linked birth and infant death records for 2011 through 2015 provided by the Texas Department of State Health Services Center for Health Statistics, separately for Hidalgo County ( $n = 80,799$ ) and for Smith County ( $n = 15,269$ ), and for Texas overall ( $n = 1,989,757$ ). We limited our analyses to women of reproductive age (15–49 y) who were Texas residents. For Texas overall, women who were not aged 15 to 49 years ( $n = 2,790$ ) or who did not have an address in Texas ( $n = 44,068$ ) were excluded. Analyses were limited to births to women aged 15 to 49 years who resided in Texas in 2011 through 2015 ( $n = 1,942,899$  births). The research study was approved by the Texas Department of State Health Services Institutional Review Board (IRB#17–055).

### Measures

The outcome of interest was infant mortality, defined as death of an infant before his or her first birthday, and was operationalized dichotomously, from the Texas linked live birth–infant cohort files for 2011 through 2015. To protect confidentiality and obtain the most accurate estimates while accounting for small frequencies for infant deaths, the 2011 through 2015 files were aggregated.

The exposures of interest were maternal sociodemographic factors and pregnancy-related characteristics. Sociodemographic factors were maternal age, education (categorized as high school graduate or less and some college or more), marital status (categorized as currently married or not), maternal race and ethnicity (categorized as Hispanic, non-Hispanic Black, non-Hispanic White, and other or unknown [American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, Other Pacific Islander, and other — not specified]), nativity (categorized as US born or not), and principal source of payment for health services (categorized as private insurance, Medicaid, and other or self-pay). Pregnancy-related characteristics were maternal cigarette smoking during pregnancy, maternal prepregnancy obesity, preexisting or gestational diabetes, prenatal care, preexisting or

gestational hypertension or eclampsia, multiple gestation (pregnant with more than 1 fetus), mother transferred for maternal or fetal indicators for delivery, and final delivery route.

All the variables are collected on the standard birth certificate and fetal death report (6). Texas implemented the revised birth certificate in 2005 and the revised fetal death report in 2006 (6). On the Texas birth certificate, preexisting and gestational diabetes are mutually exclusive conditions, as are preexisting hypertension, gestational hypertension, and eclampsia. The indication for gestational hypertension includes pregnancy-induced hypertension and preeclampsia (6). Information on cigarette smoking during pregnancy is collected as an average number of cigarettes or packs of cigarettes smoked per day during the first, second, and third trimester of pregnancy. For the purposes of this analysis, cigarette smoking was categorized as a binary variable. Mother's body mass index (BMI) was calculated based on her prepregnancy height and weight reported on the birth certificate (weight [in pounds] divided by height [in inches and squared] and the quotient multiplied by 703) (7). The Centers for Disease Control and Prevention (CDC) 2000 growth charts were used to calculate mother's age-specific BMI percentile for those aged 15 to 19 years (8). Prepregnancy weight status classified as either underweight/normal/overweight or obese was created based on age-specific BMI percentile thresholds and for those aged 15 to 19 years (9) and BMI thresholds per CDC cut points for those aged 20 years or older (10). For descriptive purposes, prenatal care was classified as yes if the mother received any prenatal care and no if the mother did not receive any prenatal care. To capture more of the variability within prenatal care, prenatal care was also assessed based on the Adequacy of Prenatal Care Utilization Index and operationalized as inadequate prenatal care, defined as prenatal care that began after the fourth month of pregnancy with the mother having less than 50% of recommended prenatal care visits, versus other categories combined (intermediate to adequate plus, ie, prenatal care that began by the fourth month of pregnancy with the mother having 50% or more of recommended prenatal care visits) (11).

### Statistical analysis

Descriptive statistics were means (SDs) and frequencies and percentage depending on the type of variable. Bivariate analyses were conducted to examine differences in the variables by infant mortality, separately for the 2 counties and for Texas overall. Multiple logistic regression models were used to examine associations of maternal sociodemographic and pregnancy-related factors with infant death, separately for the 2 counties and for Texas overall. Less than 1% of the data for the exposures were missing for the 2 counties, and approximately 10% of the data for the exposures were missing for the overall Texas model. Thus, we conducted an available case analysis. The a priori significance was set at  $\alpha = .05$ .

Estimates are presented as adjusted odds ratios (aORs) with 95% CIs. In addition, we performed a sensitivity analysis by using an alternative approach of multiple imputation using chained equations to account for missing data that were assumed to be missing at random for the overall Texas model. Twenty-five data sets were imputed for the overall model that included the variables in the corresponding analytic model. We also compared sociodemographic characteristics of those with complete versus incomplete data for the overall Texas model. All analyses were conducted in SAS/STAT software (SAS Institute, Inc) and Stata 16.0 (Stata-Corp LLC).

The causes of infant deaths for Hidalgo County, Smith County, and Texas overall were based on the underlying cause of death and were determined following the procedures used by the National Center for Health Statistics to rank causes of deaths (12,13).

In addition, by using ArcGIS Desktop, version 10.4.1 (ESRI), we mapped the distribution of IMRs and county-specific key maternal risk factors (pregnancy obesity, diabetes, hypertension, cigarette smoking during pregnancy, and prenatal care use) at the zip code level for Hidalgo and Smith counties. To obtain accurate data estimates and to control for small numbers, data for geographic areas with fewer than 100 births were suppressed. For zip code mapping purposes, we used the 2016 zip code boundaries from the ESRI Data and Maps (14).

## Results

### Maternal characteristics and infant mortality rate

The 2011 through 2015 IMRs in Hidalgo County and Smith County were 4.6 and 7.5 per 1,000 live births, respectively; the Texas IMR was 5.4 per 1,000 live births. In Hidalgo County, 97.0% of the women were Hispanic, 54.7% were married, and 35.1% had some college education, and they had a mean (SD) age of 26.4 (6.2) years. In Smith County, most women were either non-Hispanic White (49.8%) or Hispanic (29.5%), were married (57.0%), and had some college education (54.7%), and they had a mean (SD) age of 26.8 (5.7) years. Medicaid was the primary payment source for 46.6% of births in the state, 47.6% of births in Smith County, and 61.2% of births in Hidalgo County.

For Hidalgo County, a few factors differed significantly by infant death status: maternal education, maternal prepregnancy obesity, diabetes, multiple gestation, receipt of prenatal care, mother transferred for maternal or fetal indications, and delivery route (Table 1). For Smith County, factors that differed significantly by infant death status were marital status, maternal prepregnancy obesity, multiple gestation, receipt of prenatal care, mother transferred for

maternal or fetal indications, and delivery route. However, for Texas overall, most factors differed by infant death status (Table 1).

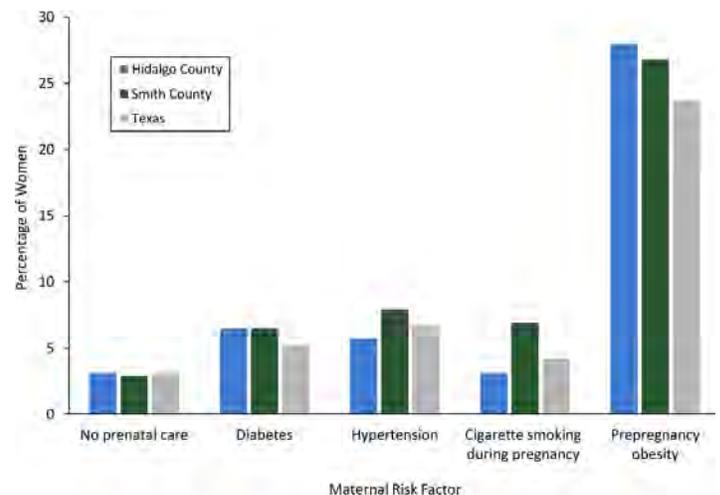
After adjusting for variables included in the model, a few variables remained significantly associated with increased odds of infant death in both counties (Table 2). In Hidalgo County, mothers who had a high school education or less (aOR, 1.48; 95% CI, 1.20–1.90), had multiple gestation (aOR, 3.67; 95% CI, 2.57–5.23), or had cesarean delivery (aOR, 1.66; 95% CI, 1.33–2.06) had higher odds of infant death. Similarly, in Smith County, mothers who were unmarried (aOR, 1.65; 95% CI, 1.14–2.40), had multiple gestation (aOR, 3.11; 95% CI, 1.58–5.60), or had cesarean delivery (aOR, 1.78; 95% CI, 1.20–2.63) had higher odds of infant death. However, for Texas overall, several sociodemographic and pregnancy-related factors were significantly associated with infant death. Mothers who had a high school education or less, were unmarried, were non-Hispanic Black, had Medicaid or other/self-pay insurance, smoked cigarettes during pregnancy, had prepregnancy obesity, maternal hypertension, multiple gestation, or cesarean delivery were at increased odds of having an infant death. To see if there were any patterns to the missing data, sociodemographic characteristics of those with complete and missing data for the variables of interest for the overall Texas model were compared. Women with missing data in the overall model were more likely have a high school education or less, Hispanic, not married, non-US born, and with Medicaid insurance. In addition, sensitivity analysis using multiple imputation methods confirmed our findings for the overall model.

### Causes of infant death

For infants born in 2015, the leading cause of infant death in both counties was congenital malformations, deformations, and chromosomal anomalies accounting for 39% and 26% of infant deaths in Hidalgo and Smith counties, respectively (Table 3). The other prevalent causes that were common to both counties were disorders related to short gestation and low birth weight, sudden infant death syndrome, and newborns affected by maternal complications of pregnancy. The 2015 ranking of leading causes for infant deaths for Hidalgo and Smith counties were similar to those for Texas overall, where the leading causes of infant death were congenital malformations, deformations, and chromosomal anomalies; disorders related to short gestation and low birthweight; sudden infant death syndrome; newborns affected by maternal complications of pregnancy; and accidents (unintentional injuries).

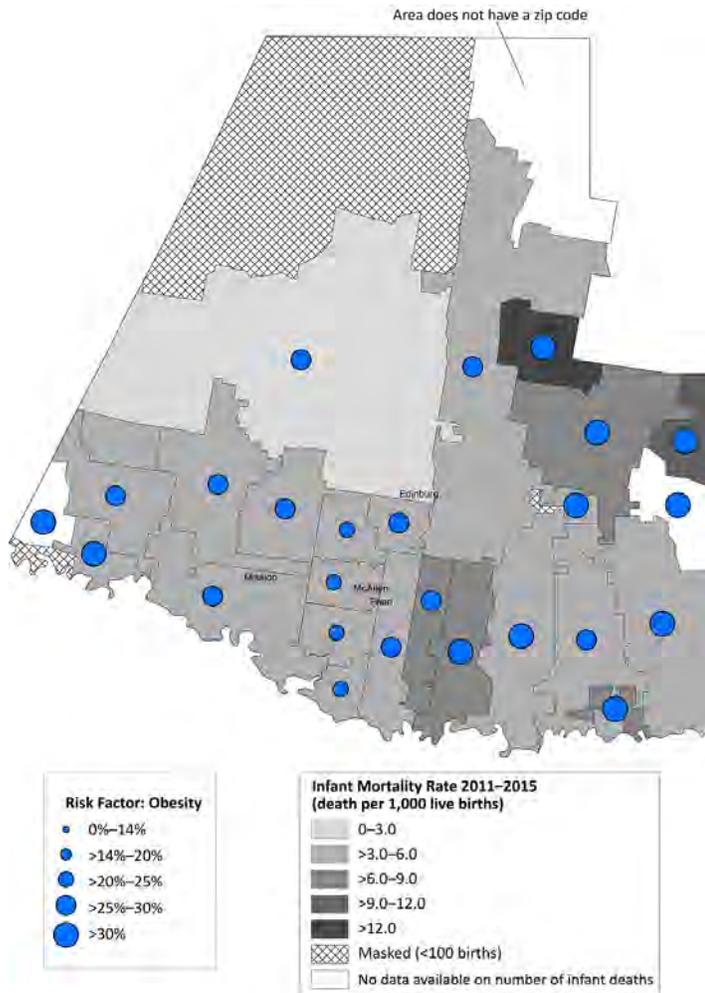
### Zip code–level distribution of infant mortality rate and key maternal risk factors

About 27% to 28% of women in the Healthy Families counties had prepregnancy obesity, whereas the state average was around 24% (Figure 1). Prevalence of no prenatal care, diabetes, and hypertension was 2.9% to 7.9% in the 2 counties, similar to state averages; however, the prevalence of maternal cigarette smoking during pregnancy in Smith County was 6.9%, which was higher than the prevalence in Hidalgo County (3.1%) and overall in the state (4.2%).

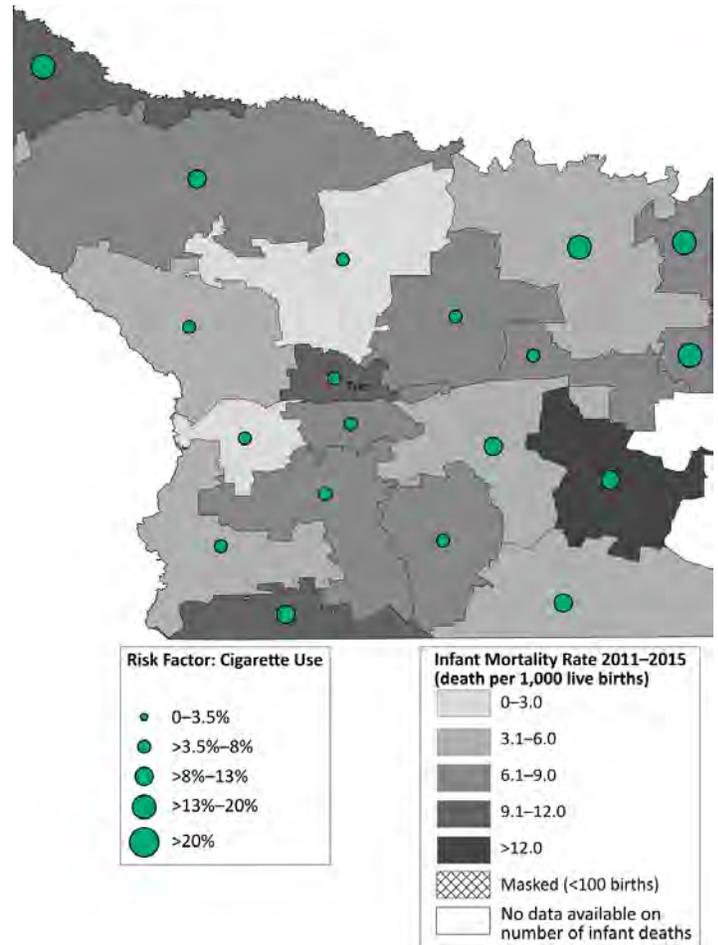


**Figure 1.** Percentage of women with key maternal risk factors, Healthy Families sites and Texas, 2011–2015. Hypertension included preexisting or gestational hypertension/preeclampsia or eclampsia; diabetes included diagnosis before pregnancy or diagnosis during pregnancy.

Most zip codes in Hidalgo County had an IMR below the state average of 5.4 per 1,000 live births (Figure 2). One zip code in the northeastern part of the county had an IMR greater than 12.0 per 1,000 live births. Hidalgo County had a high prevalence of prepregnancy obesity, particularly in those zip codes with high IMRs. Contrastingly, most zip codes in Smith County had an IMR higher than the state average (Figure 3). Most of these zip codes also had a high prevalence of maternal cigarette smoking during pregnancy.



**Figure 2.** Infant mortality rate (deaths per 1,000 live births) with prevalence of prepregnancy obesity, by zip code area, Hidalgo County, Texas, 2011–2015.



**Figure 3.** Infant mortality rate (deaths per 1,000 live births) with prevalence of cigarette smoking during pregnancy, by zip code area, Smith County, Texas, 2011–2015.

## Discussion

In the Healthy Families initiative in 2 Texas counties with high prevalences of maternal chronic conditions, we observed that several maternal sociodemographic and pregnancy-related factors were associated with higher IMR. Additionally, wide variations in IMR and key maternal risk factors were observed at a more granular geographic level within the 2 counties. Maternal marital status, education, multiple gestation, and cesarean delivery were significantly associated with infant mortality. The leading cause of infant death in both counties for infants born in 2015 was congenital malformations, deformations, and chromosomal anomalies, which was similar to Texas and the national prevalence in 2016 (12,15).

In 2011 through 2015, the IMRs in Hidalgo County and Texas were below the Healthy People 2020 objective of 6.0 per 1,000

live births; however, the rate of infant mortality in Smith County was higher than the Healthy People 2020 objective (16). Individual-level risk factors associated with IMR in the 2 selected counties are supported by prior literature: education (15), being unmarried (17), multiple gestation (18), and cesarean delivery (19); and in Texas, being non-Hispanic Black (15), having Medicaid insurance or other/self-pay (20), and having maternal risk factors such as cigarette smoking during pregnancy, prepregnancy obesity, and hypertension (3). Another potential source of the lower IMR in Hidalgo County versus Smith County and the state overall is that the health of infants with non-US-born mothers may be better than infants with US-born mothers, which was consistent with our state model but not with our county-level models (21–23). Of note, because of low frequencies of infant mortality in the 2 selected counties, some risk factors that were significant for the Texas model were not significant for the individual county models.

Within the 2 counties, geographic variations existed at the zip code level. This was particularly true in Smith County, where a few zip codes had IMRs greater than 12 per 1,000 live births, double the Healthy People 2020 objective. Further, prevalence of key maternal risk factors such as prepregnancy obesity, diabetes, hypertension, and no prenatal care in the 2 counties were similar to the state average (3); however, when examined at a more granular level, several zip codes had high rates of prepregnancy obesity. Maternal cigarette smoking prevalence in Smith County was higher than the state average of 3.6% in 2015 (3), which has yet to reach the Healthy People 2020 objective of 1.4% maternal cigarette smoking during pregnancy (16). During the Healthy Families initiative, zip code-level analyses helped identify communities at an increased risk because of a high prevalence of infant mortality and key maternal risk factors, which resulted in increased focus on these regions. For example, in both counties, community health workers focused recruitment strategies to engage women from the most disproportionately affected zip codes. In Smith County, the Nurse-Family Partnership client base was adjusted to ensure women from communities at highest risk for infant mortality were being served. In Hidalgo County, the mobile health unit that provided contraception and pregnancy-related services was parked in communities with a high prevalence of key maternal risk factors (4). In addition, in Smith County, project partners and collaborators were made aware of the high prevalence of maternal cigarette smoking in certain zip codes; these results informed smoking cessation efforts in the county.

A key limitation of our study is that we did not account for social determinants of health, including structural racism that drives infant mortality, particularly among non-Hispanic Black infants (24), which may lead to some residual confounding. Another lim-

itation is that we relied on vital records data, where medical risk factors such as diabetes, hypertension, and self-reported weight tend to be underreported compared with medical records (25–27), which may explain some of the null findings observed in the county-specific models (25). A third limitation is that we did not stratify our models by race and ethnicity because of low frequencies for infant deaths in the different groups. To reduce overadjustment bias, the models did not control for preterm birth, low birthweight, or gestational age because those are likely intermediates between maternal risk factors and infant death (28). Additionally, to maintain compliance with the data use agreement, the analyses were limited to zip code-level maps, because census tract-level analysis would result in many areas with less than 100 births over the study period. Our study had many strengths, including its large sample size, examination of several maternal factors with mutual adjustment in statistical models, and the geographic area-level analyses. Future studies should examine linking these data to more robust population health data to integrate relevant social determinants of health.

Data from this study were critical for driving strategies to better serve the health care needs of women residing in the 2 Healthy Families project sites, including focusing service delivery and outreach to maximize reach of services within disproportionately affected communities. Findings from this study were integrated into the planning, implementation, and monitoring of progress toward reducing infant mortality in the 2 counties and can inform broader efforts to improve pregnancy-related outcomes across the state.

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## Author Information

Corresponding Author: Divya A. Patel, PhD, University of Texas System — Population Health, 210 W 7th St, Austin, TX 78701. Telephone: 512-499-4589. Email: dpatel@utsystem.edu.

Author Affiliations: <sup>1</sup>University of Texas Health Science Center, Tyler, Texas. <sup>2</sup>University of Texas System Office of Health Affairs, Austin, Texas. <sup>3</sup>University of Texas Health Science Center at Houston, School of Public Health, Austin, Texas.

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**Tables**

**Table 1. Maternal Sociodemographic and Pregnancy Characteristics, Overall and by Infant Death, Healthy Families Sites and Texas, 2011–2015<sup>a</sup>**

Characteristic	Hidalgo County			Smith County			Texas		
	All Births (N = 80,621)	Infant Deaths		All Births (N = 15,253)	Infant Deaths		All Births (N = 1,942,899)	Infant Deaths	
		Yes, n = 368	No, n = 80,253		Yes, n = 115	No, n = 15,138		Yes, n = 10,622	No, n = 1,932,277
<b>Sociodemographic characteristics</b>									
Age, mean (SD), y	26.4 (6.2)	26.3 (6.9)	26.4 (6.2)	26.8 (5.7)	26.9 (5.8)	26.8 (5.7)	27.4 (6.0)	27.1 (6.5) <sup>b</sup>	27.4 (6.0) <sup>b</sup>
Missing	–	–	–	–	–	–	73	+	68
<b>Education</b>									
High school graduate or less	52,262 (64.8)	263 (71.5) <sup>b</sup>	51,999 (64.8) <sup>b</sup>	6,902 (45.3)	51 (44.4)	6,851 (45.3)	932,381 (48.0)	5,995 (56.4) <sup>b</sup>	926,386 (47.9) <sup>b</sup>
At least some college education	28,325 (35.1)	102 (27.7) <sup>b</sup>	28,223 (35.2) <sup>b</sup>	8,321 (54.7)	64 (55.7)	8,257 (54.5)	1,008,399 (52.0)	4,471 (42.1) <sup>b</sup>	1,003,928 (52.0) <sup>b</sup>
Missing	34 (0.0)	+	31 (0.0)	30 (0.2)	–	30 (0.2)	2,119 (0.1)	156 (1.5)	1,963 (0.1)
<b>Marital status</b>									
Married	44,090 (54.7)	198 (53.8)	43,892 (54.7)	8,699 (57.0)	52 (45.2) <sup>b</sup>	8,647 (57.1) <sup>b</sup>	1,126,048 (58.0)	5,261 (49.5) <sup>b</sup>	1,120,787 (58.0) <sup>b</sup>
Unmarried	36,531 (45.3)	170 (46.2)	36,361 (45.3)	6,554 (43.0)	63 (54.8) <sup>b</sup>	6,491 (42.9) <sup>b</sup>	816,829 (42.0)	5,361 (50.5) <sup>b</sup>	811,468 (42.0) <sup>b</sup>
Missing	–	–	–	–	–	–	22 (0.0)	–	22 (0.0)
<b>Race and ethnicity</b>									
Hispanic	78,216 (97.0)	359 (97.6)	77,857 (97.0)	4,493 (29.5)	28 (24.4)	4,465 (29.5)	928,453 (47.8)	4,687 (44.1) <sup>b</sup>	923,766 (47.8) <sup>b</sup>
Non-Hispanic Black	113 (0.1)	+	113 (0.1)	2,619 (17.2)	32 (27.8)	2,587 (17.1)	221,600 (11.4)	2,261 (21.3) <sup>b</sup>	219,339 (11.4) <sup>b</sup>
Non-Hispanic White	1,639 (2.0)	+	1,633 (2.0)	7,601 (49.8)	55 (47.8)	7,546 (49.9)	666,851 (34.3)	3,122 (29.4) <sup>b</sup>	663,729 (34.4) <sup>b</sup>
Other <sup>c</sup> or unknown	621 (0.8)	+	618 (0.8)	519 (3.4)	–	519 (3.4)	123,304 (6.4)	495 (4.7) <sup>b</sup>	122,809 (6.4) <sup>b</sup>
Missing	32 (0.0)	–	32 (0.0)	21 (0.1)	–	21 (0.1)	2,691 (0.1)	57 (0.5)	2,634 (0.1)
<b>US-born mother</b>									
Yes	44,517 (55.2)	213 (57.9)	44,304 (55.2)	12,158 (79.7)	96 (83.5)	12,062 (79.7)	1,401,933 (72.2)	7,998 (75.3) <sup>b</sup>	1,393,935 (72.1) <sup>b</sup>
No	36,090 (44.8)	154 (41.9)	35,936 (44.8)	3,085 (20.2)	+	3,066 (20.3)	540,212 (27.8)	2,492 (23.5) <sup>b</sup>	537,720 (27.8) <sup>b</sup>
Missing	+	+	+	+	–	+	754 (0.0)	132 (1.2)	622 (0.0)

Abbreviations: –, none reported; +, small cell size of <20 observations.

<sup>a</sup> Data presented are number (%) unless otherwise indicated. Percentages may not add up to 100 due to rounding.

<sup>b</sup> Significant difference within state or county, between infants that died and those that lived ( $P \leq .05$ ).

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<sup>d</sup> Operationalized as inadequate prenatal care, defined as prenatal care that began after the fourth month of pregnancy and the mother had less than 50% of recommended prenatal care visits, versus other categories combined (intermediate to adequate plus, ie, prenatal care that began by the fourth month of pregnancy and the mother had 50% or more of recommended prenatal care visits).

<sup>e</sup> Aged <20 years, body mass index percentile  $\geq 95$ th percentile; aged  $\geq 20$  years, body mass index  $\geq 30$ , calculated as weight (in pounds) divided by height (in inches and squared) and the quotient multiplied by 703.

<sup>f</sup> Prepregnancy or pregnancy-induced. Hypertension included preexisting or gestational hypertension/preeclampsia or eclampsia. Diabetes included diagnosis before pregnancy or diagnosis during pregnancy.

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(continued)

**Table 1. Maternal Sociodemographic and Pregnancy Characteristics, Overall and by Infant Death, Healthy Families Sites and Texas, 2011–2015<sup>a</sup>**

Characteristic	Hidalgo County			Smith County			Texas		
	All Births (N = 80,621)	Infant Deaths		All Births (N = 15,253)	Infant Deaths		All Births (N = 1,942,899)	Infant Deaths	
		Yes, n = 368	No, n = 80,253		Yes, n = 115	No, n = 15,138		Yes, n = 10,622	No, n = 1,932,277
<b>Principal source of payment</b>									
Private insurance	11,465 (14.2)	48 (13.0)	11,417 (14.2)	6,219 (40.8)	49 (42.6)	6,170 (40.8)	732,167 (37.7)	3,207 (30.2) <sup>b</sup>	728,960 (37.7) <sup>b</sup>
Medicaid	49,359 (61.2)	237 (64.4)	49,122 (61.2)	7,261 (47.6)	58 (50.4)	7,203 (47.6)	905,873 (46.6)	5,471 (51.5) <sup>b</sup>	900,402 (46.6) <sup>b</sup>
Other or self-pay	19,758 (24.5)	82 (22.3)	19,676 (24.5)	1,754 (11.5)	+	1,747 (11.5)	302,080 (15.6)	1,906 (18.0) <sup>b</sup>	300,174 (15.5) <sup>b</sup>
Missing	39 (0.1)	+	38 (0.1)	+	+	+	2,779 (0.1)	38 (0.4)	2,741 (0.1)
<b>Pregnancy-related characteristics</b>									
<b>Received prenatal care</b>									
Yes	77,144 (95.7)	330 (89.7) <sup>b</sup>	76,814 (95.7) <sup>b</sup>	13,969 (91.6)	98 (85.2) <sup>b</sup>	13,871 (91.6) <sup>b</sup>	1,868,005 (96.2)	9,240 (87.0) <sup>b</sup>	1,858,765 (96.2) <sup>b</sup>
No	2,521 (3.1)	32 (8.7) <sup>b</sup>	2,489 (3.1) <sup>b</sup>	442 (2.9)	+	429 (2.8) <sup>b</sup>	57,882 (3.0)	1,049 (9.9) <sup>b</sup>	56,833 (3.0) <sup>b</sup>
Missing	959 (1.2)	+	950 (1.2)	842 (5.5)	+	838 (5.6)	17,012 (0.9)	333 (3.1)	16,679 (0.9)
<b>Adequacy of Prenatal Care Utilization Index<sup>d</sup></b>									
Inadequate	10,578 (13.1)	40 (10.9)	10,538 (13.1)	3,198 (21.0)	20 (17.4)	3,178 (21.0)	328,303 (16.9)	1,624 (15.3) <sup>b</sup>	326,679 (16.9) <sup>b</sup>
Intermediate to adequate plus	44,113 (54.7)	197 (53.5)	43,916 (54.7)	10,521 (69.0)	73 (63.5)	10,448 (69.0)	1,429,091 (73.6)	6,607 (62.2) <sup>b</sup>	1,422,484 (73.6) <sup>b</sup>
Missing	25,930 (32.2)	131 (35.6)	25,799 (32.2)	1,534 (10.1)	22 (19.1)	1,512 (10.0)	185,505 (9.6)	2,391 (22.5)	183,114 (9.5)
<b>Presence of maternal risk factors</b>									
<b>Any cigarette smoking during pregnancy</b>									
Yes	226 (0.3)	–	226 (0.3)	1,054 (6.9)	+	1,042 (6.9)	81,112 (4.2)	749 (7.1) <sup>b</sup>	80,363 (4.2) <sup>b</sup>
No	80,391 (99.7)	366 (99.5)	80,025 (99.7)	14,194 (93.1)	103 (89.6)	14,091 (93.1)	1,861,588 (95.8)	9,858 (92.8) <sup>b</sup>	1,851,730 (95.8) <sup>b</sup>
Missing	+	+	+	+	+	+	199 (0.0)	+	184 (0.0)
<b>Prepregnancy body mass index<sup>e</sup></b>									
Obesity	22,623 (28.1)	121 (32.9) <sup>b</sup>	22,502 (28.0) <sup>b</sup>	4,092 (26.8)	41 (35.7) <sup>b</sup>	4,051 (26.8) <sup>b</sup>	463,096 (23.8)	3,099 (29.2) <sup>b</sup>	459,997 (23.8) <sup>b</sup>

Abbreviations: –, none reported; +, small cell size of <20 observations.

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<sup>e</sup> Aged <20 years, body mass index percentile  $\geq 95$ th percentile; aged  $\geq 20$  years, body mass index  $\geq 30$ , calculated as weight (in pounds) divided by height (in inches and squared) and the quotient multiplied by 703.

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Characteristic	Hidalgo County			Smith County			Texas		
	All Births (N = 80,621)	Infant Deaths		All Births (N = 15,253)	Infant Deaths		All Births (N = 1,942,899)	Infant Deaths	
		Yes, n = 368	No, n = 80,253		Yes, n = 115	No, n = 15,138		Yes, n = 10,622	No, n = 1,932,277
Overweight, normal, or underweight	57,842 (71.8)	243 (66.0) <sup>b</sup>	57,599 (71.8) <sup>b</sup>	11,083 (72.7)	72 (62.6) <sup>b</sup>	11,011 (72.8) <sup>b</sup>	1,468,790 (75.6)	7,248 (68.2) <sup>b</sup>	1,461,542 (75.6) <sup>b</sup>
Missing	156 (0.2)	+	152 (0.2)	78 (0.5)	+	76 (0.5)	11,013 (0.6)	275 (2.6)	10,738 (0.6)
Maternal diabetes <sup>f</sup>									
Yes	5,268 (6.5)	36 (9.8) <sup>b</sup>	5,232 (6.5) <sup>b</sup>	997 (6.5)	+	988 (6.5)	101,130 (5.2)	563 (5.3)	100,567 (5.2)
No	75,353 (93.5)	332 (90.2) <sup>b</sup>	75,021 (93.5) <sup>b</sup>	14,256 (93.5)	106 (92.2)	14,150 (93.5)	1,841,769 (94.8)	10,059 (94.7)	1,831,710 (94.8)
Missing	–	–	–	–	–	–	–	–	–
Maternal hypertension <sup>f</sup>									
Yes	4,564 (5.7)	25 (6.8)	4,539 (5.7)	1,213 (7.9)	+	1,201 (7.9)	129,940 (6.7)	913 (8.6) <sup>b</sup>	129,027 (6.7) <sup>b</sup>
No	76,057 (94.3)	343 (93.2)	75,714 (94.3)	14,040 (92.1)	103 (89.6)	13,937 (92.1)	1,812,959 (93.1)	9,709 (91.4) <sup>b</sup>	1,803,250 (93.3) <sup>b</sup>
Missing	–	–	–	–	–	–	–	–	–
Multiple gestation									
Yes	2,047 (2.5)	38 (10.3) <sup>b</sup>	2,009 (2.5) <sup>b</sup>	450 (3.0)	+	438 (2.9) <sup>b</sup>	62,768 (3.2)	1,406 (13.2) <sup>b</sup>	61,362 (3.2) <sup>b</sup>
No	78,574 (97.5)	330 (89.7) <sup>b</sup>	78,244 (97.5) <sup>b</sup>	14,803 (97.1)	103 (89.6) <sup>b</sup>	14,700 (97.1) <sup>b</sup>	1,880,119 (96.8)	9,216 (86.8) <sup>b</sup>	1,870,903 (96.8) <sup>b</sup>
Missing	–	–	–	–	–	–	+	–	+
Mother transferred for maternal or fetal indications for this delivery									
Yes	102 (0.1)	+	96 (0.1) <sup>b</sup>	104 (0.7)	+	101 (0.7) <sup>b</sup>	5,008 (0.3)	239 (2.3) <sup>b</sup>	4,769 (0.3) <sup>b</sup>
No	80,519 (99.9)	362 (98.4) <sup>b</sup>	80,157 (99.9) <sup>b</sup>	15,149 (99.3)	112 (97.4) <sup>b</sup>	15,037 (99.3) <sup>b</sup>	1,937,783 (99.7)	10,380 (97.7) <sup>b</sup>	1,927,403 (99.7) <sup>b</sup>
Missing	–	–	–	–	–	–	108 (0.0)	+	105 (0.0)
Final delivery route									
Vaginal	46,512 (57.7)	154 (41.9) <sup>b</sup>	46,358 (57.8) <sup>b</sup>	10,846 (71.1)	62 (53.9) <sup>b</sup>	10,784 (71.2) <sup>b</sup>	1,262,019 (65.0)	5,993 (56.4) <sup>b</sup>	1,256,026 (65.0) <sup>b</sup>
Cesarean	34,106 (42.3)	213 (57.9) <sup>b</sup>	33,893 (42.2) <sup>b</sup>	4,404 (28.9)	52 (45.2) <sup>b</sup>	4,352 (28.8) <sup>b</sup>	680,796 (35.0)	4,626 (43.6) <sup>b</sup>	676,170 (35.0) <sup>b</sup>
Missing	+	+	+	+	+	+	84 (0.0)	+	81 (0.0)

Abbreviations: –, none reported; +, small cell size of <20 observations.

<sup>a</sup> Data presented are number (%) unless otherwise indicated. Percentages may not add up to 100 due to rounding.

<sup>b</sup> Significant difference within state or county, between infants that died and those that lived ( $P \leq .05$ ).

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<sup>d</sup> Operationalized as inadequate prenatal care, defined as prenatal care that began after the fourth month of pregnancy and the mother had less than 50% of recommended prenatal care visits, versus other categories combined (intermediate to adequate plus, ie, prenatal care that began by the fourth month of pregnancy and the mother had 50% or more of recommended prenatal care visits).

<sup>e</sup> Aged <20 years, body mass index percentile  $\geq 95$ th percentile; aged  $\geq 20$  years, body mass index  $\geq 30$ , calculated as weight (in pounds) divided by height (in inches and squared) and the quotient multiplied by 703.

<sup>f</sup> Prepregnancy or pregnancy-induced. Hypertension included preexisting or gestational hypertension/preeclampsia or eclampsia. Diabetes included diagnosis before pregnancy or diagnosis during pregnancy.

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**Table 2. Associations of Maternal Sociodemographic and Pregnancy Characteristics With Infant Deaths, Healthy Families Counties and Texas, 2011–2015<sup>a</sup>**

Characteristic	Hidalgo County, aOR (95% CI) (N = 80,431)	Smith County, aOR (95% CI) (N = 15,173)	Texas, aOR (95% CI) (N = 1,744,178)
Maternal age, y	—	—	1.00 (1.00–1.01)
Education			
At least some college education	1 [Reference]	—	1 [Reference]
High school graduate or less	1.48 (1.20–1.90) <sup>b</sup>	—	1.39 (1.31–1.46) <sup>b</sup>
Marital status			
Married	—	1 [Reference]	1 [Reference]
Unmarried	—	1.65 (1.14–2.40) <sup>b</sup>	1.09 (1.03–1.15) <sup>b</sup>
Race and ethnicity			
Hispanic	—	—	1.03 (0.97–1.09)
Non-Hispanic Black	—	—	1.81 (1.69–1.94) <sup>b</sup>
Non-Hispanic White	—	—	1 [Reference]
Other <sup>c</sup> or unknown	—	—	1.04 (0.93–1.17)
US-born mother			
Yes	—	—	1 [Reference]
No	—	—	0.82 (0.77–0.87)
Principal source of payment			
Private	—	—	1 [Reference]
Medicaid	—	—	1.13 (1.06–1.20) <sup>b</sup>
Other or self-pay	—	—	1.28 (1.18–1.38) <sup>b</sup>
Any cigarette smoking during pregnancy			
No	—	—	1 [Reference]
Yes	—	—	1.56 (1.42–1.70) <sup>b</sup>
Adequacy of Prenatal Care Utilization Index <sup>d</sup>			
Intermediate to adequate plus	—	—	1 [Reference]
Inadequate	—	—	0.97 (0.91–1.02)
Prepregnancy body mass index			
Overweight, normal, or underweight	1 [Reference]	1 [Reference]	1 [Reference]
Obese <sup>e</sup>	1.12 (0.90–1.41)	1.34 (0.90–1.98)	1.22 (1.16–1.28) <sup>b</sup>
Maternal diabetes <sup>f</sup>			
No	1 [Reference]	—	—
Yes	1.40 (0.98–2.01)	—	—

Abbreviation: aOR, adjusted odds ratio; —, not included in the model because they were not significant at the bivariate level.

<sup>a</sup> Those with missing information were excluded so numbers will not align with Table 1.

<sup>b</sup> P value ≤ .05.

<sup>c</sup> American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, Other Pacific Islander, and other — not specified.

<sup>d</sup> Operationalized as inadequate prenatal care, defined as prenatal care that began after the fourth month of pregnancy and the mother had less than 50% of recommended prenatal care visits, versus other categories combined (intermediate to adequate plus, ie, prenatal care that began by the fourth month of pregnancy and the mother had 50% or more of recommended prenatal care visits).

<sup>e</sup> Aged <20 years, body mass index percentile ≥95th percentile; aged ≥20 years, body mass index ≥30, calculated as weight (in pounds) divided by height (in inches and squared) and the quotient multiplied by 703.

<sup>f</sup> Prepregnancy or pregnancy-induced. Hypertension included preexisting or gestational hypertension/preeclampsia or eclampsia. Diabetes included diagnosis before pregnancy or diagnosis during pregnancy.

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**Table 2. Associations of Maternal Sociodemographic and Pregnancy Characteristics With Infant Deaths, Healthy Families Counties and Texas, 2011–2015<sup>a</sup>**

Characteristic	Hidalgo County, aOR (95% CI) (N = 80,431)	Smith County, aOR (95% CI) (N = 15,173)	Texas, aOR (95% CI) (N = 1,744,178) <sup>b</sup>
Maternal hypertension <sup>f</sup>			
No	—	—	1 [Reference]
Yes	—	—	1.11 (1.02–1.20) <sup>b</sup>
Multiple gestation			
No	1 [Reference]	1 [Reference]	1 [Reference]
Yes	3.67 (2.57–5.23) <sup>b</sup>	3.11 (1.58–5.60) <sup>b</sup>	4.04 (3.76–4.33) <sup>b</sup>
Mother transferred for maternal or fetal indications for this delivery			
No	1 [Reference]	1 [Reference]	1 [Reference]
Yes	14.48 (6.28–33.37) <sup>b</sup>	3.53 (0.85–9.71)	6.38 (5.40–7.52) <sup>b</sup>
Final delivery route			
Vaginal	1 [Reference]	1 [Reference]	1 [Reference]
Cesarean	1.66 (1.33–2.06) <sup>b</sup>	1.78 (1.20–2.63) <sup>b</sup>	1.29 (1.23–1.36) <sup>b</sup>

Abbreviation: aOR, adjusted odds ratio; —, not included in the model because they were not significant at the bivariate level.

<sup>a</sup> Those with missing information were excluded so numbers will not align with Table 1.

<sup>b</sup> *P* value ≤ .05.

<sup>c</sup> American Indian or Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, other Asian, Native Hawaiian, Guamanian or Chamorro, Samoan, Other Pacific Islander, and other — not specified.

<sup>d</sup> Operationalized as inadequate prenatal care, defined as prenatal care that began after the fourth month of pregnancy and the mother had less than 50% of recommended prenatal care visits, versus other categories combined (intermediate to adequate plus, ie, prenatal care that began by the fourth month of pregnancy and the mother had 50% or more of recommended prenatal care visits).

<sup>e</sup> Aged <20 years, body mass index percentile ≥95th percentile; aged ≥20 years, body mass index ≥30, calculated as weight (in pounds) divided by height (in inches and squared) and the quotient multiplied by 703.

<sup>f</sup> Prepregnancy or pregnancy-induced. Hypertension included preexisting or gestational hypertension/preeclampsia or eclampsia. Diabetes included diagnosis before pregnancy or diagnosis during pregnancy.

**Table 3. Five Leading Causes of Infant Deaths, Healthy Families Sites, Infants Born in 2015**

Cause of Death <sup>a</sup> (ICD-10 Code)	Rank <sup>b</sup>	No. of deaths	Percentage of all infant deaths <sup>c</sup>
<b>Hidalgo County</b>			
All causes	—	80	100.0
Congenital malformations, deformations, and chromosomal abnormalities (Q00–Q99) <sup>d</sup>	1	31	39
Bacterial sepsis of newborn (P36) <sup>d</sup>	2	5	6
Disorders related to short gestation and low birthweight, not elsewhere classified (P07) <sup>d</sup>	3	4	5
Newborn affected by maternal complications of pregnancy (P01) <sup>d</sup>	4	3	4
Assault (*U01, X85–Y09) <sup>d</sup>	4	3	4
Diarrhea and gastroenteritis of infectious origin (A09) <sup>d</sup>	5	2	3
Sudden infant death syndrome (R95) <sup>d</sup>	5	2	3
All other causes <sup>e</sup>	—	30	38
<b>Smith County</b>			
All causes	—	23	100.0
Congenital malformations, deformations, and chromosomal abnormalities (Q00–Q99) <sup>d</sup>	1	6	26
Sudden infant death syndrome (R95) <sup>d</sup>	2	4	17
Newborn affected by maternal complications of pregnancy (P01) <sup>d</sup>	3	3	13
Disorders related to short gestation and low birthweight, not elsewhere classified (P07) <sup>d</sup>	3	3	13
Neonatal hemorrhage (P50–P52, P54) <sup>d</sup>	4	1	4
Diseases of the circulatory system (I00–I99) <sup>d</sup>	4	1	4
In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behavior (D00–D48) <sup>d</sup>	4	1	4
All other causes <sup>f</sup>	—	4	17

Abbreviations: ICD-10, International Classification of Diseases, Tenth Revision; —, not applicable.

<sup>a</sup> An asterisk preceding a cause-of-death code indicates that the code is not included in ICD-10.

<sup>b</sup> Based on number of deaths.

<sup>c</sup> Percentages may not add up to 100 because of rounding.

<sup>d</sup> Causes labeled are ranked to determine leading causes of infant death.

<sup>e</sup> All other causes include all other causes (residual) (n = 21), neonatal hemorrhage (n = 1), respiratory distress (n = 1), accidents (n = 1), newborn affected by placental complications (n = 1), hydrops fetalis (n = 1), renal failure (n = 1), congenital pneumonia (n = 1), interstitial pneumonia (n = 1), and acute bronchitis (n = 1).

<sup>f</sup> All other causes include all other causes (residual) (n = 4).

## ORIGINAL RESEARCH

# Cardiovascular Disease Risk Factors in US Adults With Vision Impairment

Isabel Mendez, MS<sup>1</sup>; Minchul Kim, PhD<sup>2</sup>; Elizabeth A. Lundeen, PhD<sup>1</sup>;  
Fleetwood Loustalot, PhD, FNP<sup>3</sup>; Jing Fang, MD, MS<sup>3</sup>; Jinan Saaddine, MD, MPH<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

A strong relationship exists between cardiovascular health and eye health, and research indicates that adults with vision impairment (VI) have a higher prevalence of cardiovascular disease (CVD) compared with those without VI.

**What is added by this report?**

We documented differences in prevalence of CVD risk factors between people with and without VI.

**What are the implications for public health practice?**

A better understanding of the relationship between VI status and CVD risk factors may aid in the prevention and management of CVD in people with VI.

## Abstract

**Introduction**

Adults with vision impairment (VI) have a higher prevalence of cardiovascular disease (CVD) compared with those without VI. We estimated the prevalence of CVD and CVD risk factors by VI status in US adults.

**Methods**

We used nationally representative data from the 2018 National Health Interview Survey (N = 22,890 adults aged ≥18 years). We estimated the prevalence of self-reported diagnosis of CVD (coronary heart disease [including angina and myocardial infarction], stroke, or other heart disease) by VI status. We used separate logistic regression models to generate adjusted prevalence ra-

tios (aPRs), controlling for sociodemographic covariates, for those with VI (reference group, no VI) for CVD and CVD risk factors: current smoking, physical inactivity, excessive alcohol intake, obesity, hypertension, high cholesterol, and diabetes.

**Results**

Overall, 12.9% (95% CI, 12.3–13.5) of the sample had VI. The prevalence of CVD was 26.6% (95% CI, 24.7–28.6) in people with VI versus 12.2% (95% CI, 11.7–12.8) in those without VI (aPR = 1.65 [95% CI, 1.51–1.80]). Compared with adults without VI, those with VI had a higher prevalence of all risk factors examined: current smoking (aPR = 1.40 [95% CI, 1.27–1.53]), physical inactivity (aPR = 1.14 [95% CI, 1.06–1.22]), excessive alcohol intake (aPR = 1.29 [95% CI, 1.08–1.53]), obesity (aPR = 1.28 [95% CI, 1.21–1.36]), hypertension (aPR = 1.29 [95% CI, 1.22–1.36]), high cholesterol (aPR = 1.21 [95% CI, 1.14–1.29]), and diabetes (aPR = 1.54 [95% CI, 1.38–1.72]).

**Conclusion**

Adults with VI had a higher prevalence of CVD and CVD risk factors compared with those without VI. Effective clinical and lifestyle interventions, adapted to accommodate VI-related challenges, may help reduce CVD risk in adults with VI.

## Introduction

Cardiovascular disease (CVD), including heart disease, stroke and vascular disease, is a major cause of illness and death in the US, claiming 800,000 lives each year (1). CVD contributes \$363 billion annually in health care costs and lost productivity (1).

CVD can be prevented or delayed through lifestyle modifications to control or manage risk factors. Approximately 34% of deaths from heart disease could be prevented by modifying key risk factors (2). The American Heart Association (AHA) promotes Life's Simple 7 (LS7) (3), which identifies and quantifies 7 factors that influence cardiovascular health (smoking status, physical activity, body weight, diet, blood pressure, cholesterol, and blood



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glucose), with higher LS7 scores associated with better cardiovascular health and lower risk of all-cause and CVD mortality (1,4).

A strong connection between cardiovascular health and eye health has been noted (5); they share risk factors such as older age, current smoking, high blood glucose, and hypertension. One study found that adults aged 40 years or older who had better cardiovascular health had lower odds of ocular diseases such as age-related macular degeneration (AMD), diabetic retinopathy, cataract, and glaucoma (5). Research has also shown that compared with adults without vision impairment (VI), those with VI have a higher prevalence of CVD, contributing to increased mortality risk among the 7 million Americans with VI (6,7). A study of US adults aged 65 years or older found that compared with people without VI, people with VI had a higher prevalence of 13 self-reported chronic conditions, including heart disease and stroke (7).

Although studies have examined the relationship between VI and CVD (7–9), less is known about differences in prevalence of CVD risk factors between people with and without VI. Better understanding the relationship between VI and CVD risk factors may aid in prevention and management of CVD among those with VI. Our objective was to assess the relationship between VI and CVD risk factors in US adults.

## Methods

We analyzed publicly available, de-identified data from the sample adult core questionnaire of the 2018 National Health Interview Survey (NHIS). The NHIS is an annual, cross-sectional, in-person household interview survey of US noninstitutionalized civilians in all 50 states and the District of Columbia. The NHIS is among the primary data collection programs of the Centers for Disease Control and Prevention's (CDC's) National Center for Health Statistics and is a principal source of information on health outcomes, risk factors, and behaviors in the US. The NHIS uses a complex probability sampling strategy to select households and individuals, and estimates are weighted to represent the US adult civilian population. Respondents provided oral consent before participation, and the survey was approved by CDC's Research Ethics Review Board and the US Office of Management and Budget.

### Study sample

The sample adult component contained data for 25,417 respondents aged 18 years or older and had an unconditional final response rate of 53.1% in 2018 (10). We excluded pregnant people and those missing data on self-reported CVD, CVD risk factors, and VI ( $n = 2,527$ ), yielding a final analytic sample of 22,890 adults.

## Measures

Our exposure was self-reported VI and was characterized as an affirmative response to the question: "Do you have difficulty seeing, even when wearing glasses?" The outcomes we investigated were self-reported CVD and 7 CVD risk factors. Self-reported CVD was ascertained by asking whether the respondent had ever been told by a doctor or other health professional that they had any of the following conditions: coronary heart disease, angina/angina pectoris, heart attack/myocardial infarction, stroke, or any kind of heart condition or heart disease. Using AHA's LS7 as a framework, we selected 7 self-reported CVD risk factors from the NHIS to examine cardiovascular health: current smoking, physical inactivity, excessive alcohol intake, obesity, hypertension, high cholesterol, and diabetes. Because NHIS does not regularly collect dietary data as part of its core survey content, dietary data were not collected in 2018 and could not be used; because the consumption of alcohol has complex effects on cardiovascular health, we included excessive alcohol intake in place of poor diet as a CVD risk factor (11). The self-reported CVD risk factors were separated into 2 categories: 1) risk behaviors: current smoking, physical inactivity, and excessive alcohol intake; and 2) health conditions: obesity, hypertension, high cholesterol, diabetes. The 3 risk behaviors were characterized as: current smoker (defined as those who had smoked more than 100 cigarettes in their lifetime and now smoke every day or some days), physical inactivity (defined as performing <10 minutes per week of light, moderate, or vigorous leisure-time physical activities), excessive alcohol intake (defined as consuming  $\geq 12$  drinks in their lifetime and >14 drinks/week in past year [for men] or >7 drinks/week in past year [for women]). Alcohol intake for the full adult sample was used for analyses; however, in the US the Minimum Legal Drinking Age (MLDA) has been 21 years since 1984 (12). The 4 health conditions were obesity (body mass index  $>30$  kg/m<sup>2</sup>, calculated using self-reported height and weight) and self-reported hypertension, high cholesterol, and diabetes, which were defined as an affirmative response to the question of whether the respondent had ever been told by a doctor or other health professional that they had hypertension or high blood pressure, high cholesterol, or diabetes or sugar diabetes, respectively. The NHIS does not directly measure blood pressure or collect biospecimens, so self-reported factors were used as proxy assessments.

Sociodemographic characteristics were age, sex, race and ethnicity (non-Hispanic Black, Hispanic, non-Hispanic White, and other racial/ethnic groups), education (less than high school, high school/general educational development, more than high school), marital status (married/domestic partnership, not married [including widowed, divorced, separated, or never married]), employment status (work for pay at job/business, not working for pay),

health insurance (public, private, both, none), and family income-to-poverty threshold ratio (<1, 1 to <2, ≥2) based on the US Census Bureau federal poverty thresholds (<https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html>).

### Statistical analysis

Descriptive characteristics of the study population were tabulated, stratified by VI status. We used separate logistic regression models to generate adjusted prevalence ratios (aPRs) for those with VI (reference: no VI) for CVD and the 7 CVD risk factors. Models for each outcome controlled for age (as a continuous variable), sex, race and ethnicity, education level, marital status, employment status, income-to-poverty ratio, and health insurance. We examined the effect modification of the relationship between VI, CVD, and the 7 CVD risk factors by calculating the aPR for each age group (18–44 y, 45–64 y, ≥65 y) derived from a model that included an interaction term between VI and age group. We used  $\chi^2$  tests to examine whether the prevalence of VI varied by sociodemographic characteristics (differences considered significant at  $P < .05$ ). We also determined the distribution of respondents by the number of CVD risk factors and VI status. All analyses accounted for complex survey design and sampling weights. Weighted analyses were performed using STATA version 16 (StataCorp LLC).

### Results

Nearly half of adults in this study were aged 18 to 44 years (46.3%), and most were non-Hispanic White (63.9%), had more than a high school education (64.7%), were married (60.3%), worked for pay at a job or business (63.0%), had an income-to-poverty ratio of 2 or more (73.3%), and had private health insurance (54.6%) (Table 1). Overall, 12.9% (95% CI, 12.3–13.5) of adults had self-reported VI. Compared with adults without VI, those with VI tended to be older (≥45 years), female, non-Hispanic Black, not married, and not working for pay and to have a high school education or less, an income-to-poverty ratio of <1 or 1 to <2, and public health insurance. Overall, the prevalence of CVD among adults was 14.1% (95% CI, 13.5–14.7) (Table 2). Prevalence of CVD was 26.6% (95% CI, 24.7–28.6) in respondents with VI and 12.2% (95% CI, 11.7–12.8) in those without VI (prevalence ratio [PR] = 2.18 [95% CI, 2.00–2.37]). In unadjusted analyses, respondents with VI had a significantly higher prevalence of CVD and 6 of the 7 CVD risk factors. After adjusting for sociodemographic factors, compared with adults without VI, those with VI had a higher prevalence of CVD (aPR = 1.65 [95% CI, 1.51–1.80]) and all 3 CVD risk behaviors: current smoking (aPR = 1.40 [95% CI, 1.27–1.53]), physical inactivity (aPR = 1.14 [95%

CI, 1.06–1.22]), and excessive alcohol intake (aPR = 1.29 [95% CI, 1.08–1.53]). Additionally, in adjusted analyses, respondents with VI had a higher prevalence of all 4 self-reported health conditions: obesity (aPR = 1.28 [95% CI, 1.21–1.36]), hypertension (aPR = 1.29 [95% CI, 1.22–1.36]), high cholesterol (aPR = 1.21 [95% CI, 1.14–1.29]), and diabetes (aPR = 1.54 [95% CI, 1.38–1.72]). In models examining effect modification by age group, the aPR was higher for CVD and several CVD risk factors among the younger age groups (18–44 years and 45–64 years) compared with the older age group (≥65 years); however, this effect modification was only significant ( $P < .05$ ) for 3 models (CVD, hypertension, and diabetes) (Table 3). Overall, compared with adults without VI, those with VI had a higher number of CVD risk factors (Table 4). Among those with VI, more than 61% reported having 2 or more CVD risk factors, whereas 40% of those without VI did.

### Discussion

Our analysis of this nationally representative sample of US adults showed that respondents with VI had a higher prevalence of CVD than those without VI. Approximately 1 in 4 adults with VI reported a CVD diagnosis; approximately 1 in 10 of respondents without VI reported a CVD diagnosis. This finding was consistent with that of a previous study (7). We also found that after adjusting for sociodemographic factors, adults with VI had a higher prevalence of all 7 CVD risk factors that were examined. Furthermore, the relationship between VI and the outcomes of CVD and several CVD risk factors was stronger in the younger age groups. Additionally, more than half of adults with VI reported having 2 or more CVD risk factors (vs 40% among those without VI). Our study adds to existing literature on the relationship between VI and CVD risk factors and strengthens the evidence by examining this relationship among a nationally representative sample of adults aged 18 years or older. Additionally, our study measured general VI, whereas most studies examined CVD risk factors and selected age-related eye diseases (13,14), thereby excluding those who may have VI from other forms of eye conditions.

Prior studies examining VI and CVD risk factors have investigated associations between specific types of eye disease and individual CVD risk factors such as AMD and smoking or glaucoma and hypertension (13–17). For example, one population-based, cross-sectional study examining the association of CVD risk factors and AMD found a strong association between current daily smoking and AMD — a leading cause of vision loss for people aged 50 years or older (18). This finding is consistent with our finding that, compared with adults without VI, those with VI had a 40% higher likelihood of being a current smoker. The same study also found sex differences in the association between late AMD

(the most severe form of this eye disease) and CVD risk factors. Although the association between AMD and smoking was significant among both men and women, only women had a significant association between late AMD and current smoking, and the same was true for the relationship between late AMD and other CVD risk factors such as obesity, hypertension, and physical inactivity (18). A proposed explanation for this finding is that women generally have a longer life expectancy than men and are therefore more likely to have a longer duration of smoking and greater likelihood of progressing to late-stage AMD, a condition which significantly affects the central vision needed for activities of daily living (19).

Our findings also demonstrate that adults with VI had a 29% higher likelihood of reporting excessive alcohol intake when compared with people without VI. Because our study used cross-sectional data, we were unable to establish temporality or causality for this relationship. However, a longitudinal study examining the relationship of smoking, alcohol consumption, and physical activity to changes in vision over a 20-year period found that people with heavy alcohol consumption had 2.66 times greater odds of incident VI compared with those with occasional alcohol consumption (20). Other studies have reported contradictory results on the associations of alcohol consumption and eye disease, and additional research could elucidate the effects of alcohol on the risk of VI (21). The relationship between CVD and alcohol consumption is complex; however, heavier consumption has generally been associated with negative CVD outcomes. A study investigating health problems associated with alcohol consumption found that CVD was among the most common diseases linked to alcohol consumption, particularly heavy drinking (22). It found that although the overall effect of alcohol consumption on CVD was detrimental, the dose–response relationship differed for different conditions. For example, hypertension risk had a linear relationship with alcohol consumption, indicating an almost entirely detrimental effect. However, for heart disease the association with alcohol consumption showed a J-shaped curve, indicating some protective effects with regular light drinking. This finding is consistent with other studies that have found health benefits to moderate alcohol consumption and an increased risk of illness and death with excessive alcohol consumption (23–25).

One expected finding of our study was that the largest effect size was for the CVD risk factor of diabetes; when compared with adults without VI, those with VI had a 54% higher likelihood of having diabetes. However, the cross-sectional data we used allow only for an assessment of correlation, not causation. Diabetes may have preceded VI, as 1 in 3 people with diabetes will develop diabetic retinopathy, a potentially vision-threatening condition (26). Other studies have shown significant associations between diabetes, poor glycemic control, and other vision-damaging condi-

tions such as glaucoma and cataracts (27). Our study demonstrates a relationship between vision health, diabetes, and CVD health, which is consistent with a recent study that used data from the National Health and Nutrition Examination Survey to examine the association between ideal cardiovascular health and ocular diseases among US adults (5). The study found that 84% of participants with diabetic retinopathy were observed to have inadequate cardiovascular health and that a 1-unit increase in the LS7 ideal cardiovascular health score reduced the odds of diabetic retinopathy by 31% (5). Because of the connection between cardiovascular health and diabetic retinopathy risk, it is important for health care professionals to coordinate CVD management and diabetes care to prevent worsening of chronic disease and increased risk of VI.

Our results showed that 3 in 5 people with VI had multiple CVD risk factors. The 2 most prevalent risk factors among those with VI were hypertension and obesity, with more than 2 in 5 reporting hypertension and nearly 1 in 2 reporting obesity. One US study using nationally representative data found that the odds of having obesity were 1.5 times higher among people with blindness or low vision than the general population (28). Physical activity has been well established as a preventive measure for various chronic diseases including CVD (29). However, engaging in traditional physical activities may be difficult for people with VI. In fact, our study found that adults with VI were more likely to be physically inactive compared with those without VI, although it is unknown whether their activity level preceded VI. Providing physical activity opportunities and health promotion activities for adults with VI is vital to improve health outcomes among this population because evidence has shown that people with VI often have higher rates of poorer health, including overweight and obesity (28). Although this need has been recognized, most health promotion interventions have focused on low-intensity and balance activities for older adults (29). Data on evidence-based health promotion interventions tailored for younger, working-aged adults with VI are limited (29). In addition to tailored lifestyle interventions, clinical intervention could play a key role in preventing disease progression among people with VI. For example, an ophthalmology report reviewing smoking and VI found that advice on smoking cessation from eye care providers increased the odds of quitting smoking by 30% (30).

### Limitations

Our findings are subject to several limitations. First, NHIS consists of self-reported data and can be subject to recall and reporting bias. Second, due to the cross-sectional design of NHIS, causality cannot be established. Third, because NHIS-measured dietary data were not collected in 2018, as they are only collected every 5 years through a sponsored module, we could not use the

exact LS7 factors that influence cardiovascular health. We instead used other self-reported CVD risk factor data, such as alcohol consumption, obesity, and diabetes, as proxies for LS7's diet, body weight, and blood glucose cardiovascular health metrics, respectively. Lastly, although NHIS is nationally representative, it is only administered to noninstitutionalized adults, thus excluding those living in long-term care facilities or institutional settings where the prevalence of VI and chronic health conditions tends to be higher than that in the general population.

## Conclusions

Our results show that adults with VI had a higher prevalence of CVD and CVD risk factors compared with those without VI. The relationship between VI and several CVD risk factors was stronger in the younger age group, demonstrating the potential benefits of early effective clinical and lifestyle interventions, adapted to accommodate VI-related disability to aid in reducing CVD risk in adults with VI. Furthermore, because this association could be bidirectional, integrating vision health into routine clinical care and chronic disease prevention into routine vision services could be beneficial in the prevention and management of CVD and VI.

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Ms. Mendez conducted the literature search, contributed to conceptualization, and wrote the manuscript. Dr Lundeen contributed to conceptualization and methodology. Dr Kim curated and analyzed the data. Dr Saaddine provided supervision. All authors reviewed and edited the manuscript. An abstract form of this study was presented at the 2021 Association for Research in Vision and Ophthalmology annual meeting. No financial disclosures were reported by the authors of this article. No conflicts of interest were reported by the authors. No copyrighted materials or tools were used for this research. 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.

## Author Information

Corresponding Author: Isabel Mendez, MS, Centers for Disease Control and Prevention, 4770 Buford Hwy NE, Mail Stop S107-3, Atlanta, GA 30341. Telephone: 404-498-2962. Email: [prz3@cdc.gov](mailto:prz3@cdc.gov).

Author Affiliations: <sup>1</sup>Division of Diabetes Translation, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia. <sup>2</sup>University of Illinois College of Medicine, Peoria, Illinois. <sup>3</sup>Division for Heart Disease and Stroke Prevention, National

Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia.

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Tables

**Table 1. Selected Characteristics of Adults Aged ≥18 Years, by Self-Reported Vision Status, Study of Cardiovascular Disease Risk Factors in US Adults With Vision Impairment, 2018**

Characteristic	All, % (95% CI) (N = 22,890)	Distribution by vision status, % (95% CI) <sup>a</sup>	
		Vision impairment (n = 3,214)	No vision impairment (n = 19,676)
Age, y <sup>b</sup>			
18–44	46.3 (45.3–47.3)	31.1 (28.9–33.3)	48.5 (47.5–49.6)
45–64	33.4 (32.6–34.2)	40.8 (38.7–43.0)	32.3 (31.4–33.1)
≥65	20.3 (19.6–21.0)	28.1 (26.3–29.9)	19.2 (18.4–19.9)
Sex <sup>b</sup>			
Male	48.8 (47.6–49.2)	43.0 (40.8–45.2)	49.7 (48.9–50.5)
Female	51.2 (50.4–51.9)	57.0 (54.8–59.2)	50.3 (49.5–51.1)
Race and ethnicity <sup>b</sup>			
Black, non-Hispanic	11.2 (10.3–12.1)	14.0 (12.2–16.0)	10.8 (9.9–11.7)
Hispanic	16.0 (14.7–17.4)	16.0 (13.9–18.3)	16.0 (14.7–17.4)
Other	8.9 (8.1–9.7)	7.4 (6.0–9.1)	9.1 (8.3–10.0)
White, non-Hispanic	63.9 (62.3–65.5)	62.6 (59.9–65.3)	64.1 (62.5–65.7)
Education level <sup>b</sup>			
Less than high school	11.0 (10.3–11.8)	14.8 (13.2–16.5)	10.4 (9.7–11.2)
High school/GED	24.3 (23.4–25.1)	27.6 (25.6–29.8)	23.8 (22.9–24.7)
More than high school	64.7 (63.6–65.8)	57.6 (55.3–59.9)	65.8 (64.6–66.9)
Marital status <sup>b</sup>			
Married/domestic partnership	60.3 (59.4–61.2)	54.7 (52.5–56.8)	61.2 (60.2–62.1)
Not married <sup>c</sup>	39.7 (38.8–40.6)	45.3 (43.2–47.5)	38.8 (37.9–39.8)
Employment status <sup>b</sup>			
Work for pay at job/business	63.0 (62.1–64.0)	46.7 (44.4–48.9)	65.5 (64.5–66.4)
Not working for pay	37.0 (36.0–37.9)	53.3 (51.1–55.6)	34.5 (33.6–35.5)
Income-to-poverty ratio <sup>b,d</sup>			
<1	10.0 (9.4–10.6)	15.0 (13.5–16.6)	9.2 (8.6–9.8)
1 to <2	16.7 (16.0–17.5)	22.9 (21.1–24.9)	15.8 (15.0–16.6)
≥2	73.3 (72.3–74.4)	62.1 (59.7–64.3)	75.0 (73.9–76.0)
Health insurance <sup>b</sup>			
Public	23.9 (23.0–24.8)	36.2 (33.9–38.5)	22.0 (21.2–22.9)
Private	54.6 (53.5–55.7)	39.0 (36.6–41.3)	56.9 (55.7–58.0)
Both	11.4 (10.8–12.0)	14.7 (13.3–16.2)	10.9 (10.3–11.5)
None	10.2 (9.5–10.8)	10.2 (8.7–11.8)	10.2 (9.5–10.9)

Abbreviation: GED, general education development.

<sup>a</sup> Percentages are weighted and may not add up to 100% due to rounding.

<sup>b</sup> Prevalence of vision impairment varied by sociodemographic characteristic ( $P < .05$ ,  $\chi^2$  test).

<sup>c</sup> Widowed, divorced, separated, or never married.

<sup>d</sup> Ratio of the family income to the poverty threshold, based on the US Census Bureau federal poverty thresholds given the family's size and number of children (<https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html>).

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**Table 2. Prevalence and Prevalence Ratio of Self-Reported Cardiovascular Disease and Cardiovascular Disease Risk Factors Among US Adults Aged ≥18 Years, by Vision Status, 2018**

Risk factor	Total prevalence, % (95% CI) <sup>a</sup>	Prevalence by vision status, % (95% CI) <sup>a</sup>		PR (95% CI) <sup>b</sup>	aPR (95% CI) <sup>c</sup>
		Vision impairment	No vision impairment		
<b>Cardiovascular disease<sup>d</sup></b>	14.1 (13.5–14.7)	26.6 (24.7–28.6)	12.2 (11.7–12.8)	2.18 (2.00–2.37)	1.65 (1.51–1.80)
<b>Risk behaviors</b>					
Current smoking <sup>e</sup>	13.8 (13.2–14.4)	19.5 (17.9–21.1)	13.0 (12.3–13.6)	1.50 (1.37–1.64)	1.40 (1.27–1.53)
Physical inactivity <sup>f</sup>	25.7 (24.7–26.8)	34.6 (32.4–36.9)	24.4 (23.3–25.5)	1.42 (1.33–1.51)	1.14 (1.06–1.22)
Excessive alcohol intake <sup>g</sup>	5.3 (4.9–5.6)	6.0 (5.2–7.1)	5.2 (4.8–5.5)	1.17 (0.99–1.39)	1.29 (1.08–1.53)
<b>Health conditions</b>					
Obesity <sup>h</sup>	33.0 (32.2–33.9)	42.4 (40.1–44.7)	31.7 (30.7–32.6)	1.34 (1.26–1.42)	1.28 (1.21–1.36)
Hypertension <sup>i</sup>	31.7 (30.9–32.5)	47.5 (45.2–49.7)	29.3 (28.5–30.2)	1.62 (1.53–1.71)	1.29 (1.22–1.36)
High cholesterol <sup>i</sup>	27.9 (27.1–28.7)	38.5 (36.5–40.6)	26.3 (25.5–27.1)	1.46 (1.38–1.55)	1.21 (1.14–1.29)
Diabetes <sup>i</sup>	10.1 (9.6–10.6)	18.5 (16.8–20.3)	8.9 (8.4–9.3)	2.09 (1.88–2.32)	1.54 (1.38–1.72)

Abbreviations: CVD, cardiovascular disease; PR, prevalence ratio; aPR, adjusted prevalence ratio.

<sup>a</sup> Percentages are weighted percentages and may not add up to 100% due to rounding.

<sup>b</sup> Separate logistic regression models were performed to generate prevalence ratios for CVD and each CVD risk factor, comparing the prevalence among those with vision impairment to the prevalence of those without vision impairment.

<sup>c</sup> Adjusted for age (continuous variable), sex, race and ethnicity, education, marital status, employment status, income-to-poverty ratio, and health insurance status.

<sup>d</sup> Self-reported CVD ascertained by asking whether respondent has ever been told by a doctor or other health professional that they had any of the following conditions: coronary heart disease, angina/angina pectoris, heart attack/myocardial infarction, stroke, or any kind of heart condition or heart disease.

<sup>e</sup> Current smoker was defined as those who had smoked more than 100 cigarettes in their lifetime and now smoke every day or some days.

<sup>f</sup> Physical inactivity was defined as performing <10 min per week of light, moderate, or vigorous leisure-time physical activities.

<sup>g</sup> Excessive alcohol intake was defined as consuming ≥12 drinks in lifetime and >14 drinks/week in past year (for men) or >7 drinks/week in past year (for women).

<sup>h</sup> Obesity was defined as a body mass index >30. Body mass index was calculated, using self-reported data, as weight (in kilograms) divided by height (in meters) squared.

<sup>i</sup> Health conditions were defined as an affirmative response to the question of whether the respondent had ever been told by a doctor or other health professional that they had 1) hypertension or high blood pressure, 2) high cholesterol, or 3) diabetes or sugar diabetes.

**Table 3. Prevalence of Self-Reported Cardiovascular Disease Risk Factors Among US Adults ≥18 Years, by Vision Status and Age Group, 2018**

Risk factor	Total prevalence, % (95% CI) <sup>a</sup>	Prevalence by vision status % (95% CI) <sup>a</sup>		PR (95% CI) <sup>b</sup>	aPR (95% CI) <sup>c</sup>
		Vision impairment	No vision impairment		
<b>Cardiovascular disease<sup>d</sup></b>					
18–44 y	5.4 (4.9–6.1)	13.4 (10.5–16.9)	4.7 (4.2–5.3)	2.85 (2.19–3.72)	2.53 (1.95–3.28)
45–64 y	14.1 (13.1–15.1)	25.2 (22.3–28.3)	12.0 (11.1–13.0)	2.10 (1.83–2.41)	1.78 (1.55–2.05)
≥65 y	33.8 (32.4–35.3)	43.4 (40.0–46.7)	31.7 (30.2–33.3)	1.37 (1.25–1.49)	1.38 (1.25–1.53)
<b>Risk behaviors</b>					
<b>Current smoking<sup>e</sup></b>					
18–44 y	14.3 (13.4–15.3)	20.7 (17.5–24.4)	13.7 (12.8–14.7)	1.51 (1.27–1.80)	1.36 (1.14–1.62)
45–64 y	16.3 (15.2–17.4)	24.4 (21.6–27.5)	14.7 (13.7–15.8)	1.66 (1.45–1.89)	1.40 (1.22–1.59)
≥65 y	8.6 (7.8–9.4)	10.9 (9.0–13.2)	8.1 (7.3–8.9)	1.35 (1.09–1.68)	1.22 (0.97–1.53)
<b>Physical inactivity<sup>f</sup></b>					
18–44 y	20.3 (19.0–21.7)	25.5 (21.5–30.0)	19.8 (18.5–21.2)	1.29 (1.09–1.53)	1.10 (0.92–1.31)
45–64 y	26.5 (25.0–28.0)	34.8 (31.6–38.2)	24.9 (23.4–26.5)	1.40 (1.26–1.55)	1.15 (1.04–1.28)
≥65 y	36.9 (35.3–38.6)	44.2 (40.7–47.8)	35.3 (33.6–37.1)	1.25 (1.15–1.37)	1.16 (1.05–1.28)
<b>Excessive alcohol intake<sup>g</sup></b>					
18–44 y	5.4 (4.9–6.0)	7.1 (5.4–9.4)	5.3 (4.7–5.8)	1.35 (1.01–1.81)	1.45 (1.08–1.94)
45–64 y	5.7 (5.1–6.3)	6.5 (5.3–8.1)	5.5 (4.9–6.2)	1.19 (0.93–1.51)	1.29 (1.02–1.65)
≥65 y	4.3 (3.7–4.9)	4.1 (3.0–5.7)	4.3 (3.7–5.0)	0.97 (0.68–1.38)	1.02 (0.72–1.46)
<b>Health conditions</b>					
<b>Obesity<sup>h</sup></b>					
18–44 y	30.6 (29.3–31.9)	41.4 (36.8–46.2)	29.6 (28.2–30.9)	1.40 (1.24–1.58)	1.33 (1.19–1.50)
45–64 y	37.3 (35.9–38.7)	47.2 (43.8–50.6)	35.4 (33.9–37.0)	1.33 (1.23–1.45)	1.26 (1.16–1.37)
≥65 y	31.7 (30.3–33.0)	36.4 (33.2–39.8)	30.6 (29.1–32.2)	1.19 (1.07–1.32)	1.18 (1.05–1.32)
<b>Hypertension<sup>i</sup></b>					
18–44 y	12.1 (11.3–13.0)	22.2 (18.6–26.2)	11.2 (10.4–12.0)	1.99 (1.66–2.39)	1.82 (1.52–2.19)
45–64 y	39.5 (38.2–40.9)	50.6 (47.2–54.1)	37.5 (36.0–38.9)	1.35 (1.25–1.46)	1.24 (1.15–1.34)
≥65 y	63.4 (62.0–64.7)	70.7 (67.6–73.6)	61.7 (60.2–63.2)	1.15 (1.09–1.20)	1.16 (1.09–1.23)

Abbreviations: aPR, adjusted prevalence ratio; CVD, cardiovascular disease; PR, prevalence ratio.

<sup>a</sup> Because of rounding, weighted percentages may not add up to 100%. Sample sizes (unweighted) were n = 8,771 for adults aged 18–44 years, n = 7,670 for adults aged 45–64 years, and n = 6,449 for adults aged ≥65 years.

<sup>b</sup> Separate logistic regression models with STATA's *adjrr* command were performed to generate prevalence ratios for CVD and each CVD risk factor, comparing the prevalence among those with vision impairment to the prevalence of those without vision impairment. Each model contained an interaction term between vision impairment and age group to test effect modification by age.

<sup>c</sup> Adjusted for sex, race and ethnicity, education, marital status, employment status, income-to-poverty ratio, and health insurance status.

<sup>d</sup> Self-reported cardiovascular disease ascertained by asking whether respondent has ever been told by a doctor or other health professional that they had any of the following conditions: coronary heart disease, angina/angina pectoris, heart attack/myocardial infarction, stroke, or any kind of heart condition or heart disease.

<sup>e</sup> Current smoker was defined as those who had smoked more than 100 cigarettes in their lifetime and now smoke every day or some days.

<sup>f</sup> Physical inactivity was defined as performing <10 min per week of light, moderate, or vigorous leisure-time physical activities.

<sup>g</sup> Excessive alcohol intake was defined as consuming ≥12 drinks in lifetime and >14 drinks/week in past year (for men) or >7 drinks/week in past year (for women).

<sup>h</sup> Obesity was defined as a body mass index >30. Body mass index was calculated, using self-reported data, as weight (in kilograms) divided by height (in meters) squared.

<sup>i</sup> Health conditions were defined as an affirmative response to the question of whether the respondent had ever been told by a doctor or other health professional that they had 1) hypertension or high blood pressure, 2) high cholesterol, or 3) diabetes or sugar diabetes.

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(continued)

**Table 3. Prevalence of Self-Reported Cardiovascular Disease Risk Factors Among US Adults ≥18 Years, by Vision Status and Age Group, 2018**

Risk factor	Total prevalence, % (95% CI) <sup>a</sup>	Prevalence by vision status % (95% CI) <sup>a</sup>		PR (95% CI) <sup>b</sup>	aPR (95% CI) <sup>c</sup>
		Vision impairment	No vision impairment		
High cholesterol <sup>i</sup>					
18–44 y	9.7 (9.0–10.5)	15.2 (12.2–18.9)	9.2 (8.5–10.0)	1.66 (1.32–2.09)	1.60 (1.29–2.00)
45–64 y	36.9 (35.6–38.2)	42.9 (39.5–46.5)	35.8 (34.4–37.2)	1.20 (1.10–1.31)	1.16 (1.07–1.27)
≥65 y	54.6 (53.2–56.0)	57.9 (54.4–61.3)	53.9 (52.3–55.4)	1.07 (1.01–1.15)	1.10 (1.02–1.19)
Diabetes <sup>i</sup>					
18–44 y	3.2 (2.8–3.7)	8.7 (6.2–11.9)	2.7 (2.3–3.1)	3.19 (2.23–4.54)	2.71 (1.92–3.82)
45–64 y	12.5 (11.6–13.6)	21.7 (18.8–25.0)	10.8 (9.9–11.8)	2.01 (1.71–2.35)	1.66 (1.41–1.94)
≥65 y	21.7 (20.6–23.0)	24.7 (21.9–27.7)	21.1 (19.8–22.5)	1.17 (1.02–1.34)	1.11 (0.96–1.28)

Abbreviations: aPR, adjusted prevalence ratio; CVD, cardiovascular disease; PR, prevalence ratio.

<sup>a</sup> Because of rounding, weighted percentages may not add up to 100%. Sample sizes (unweighted) were n = 8,771 for adults aged 18–44 years, n = 7,670 for adults aged 45–64 years, and n = 6,449 for adults aged ≥65 years.

<sup>b</sup> Separate logistic regression models with STATA's *adjrr* command were performed to generate prevalence ratios for CVD and each CVD risk factor, comparing the prevalence among those with vision impairment to the prevalence of those without vision impairment. Each model contained an interaction term between vision impairment and age group to test effect modification by age.

<sup>c</sup> Adjusted for sex, race and ethnicity, education, marital status, employment status, income-to-poverty ratio, and health insurance status.

<sup>d</sup> Self-reported cardiovascular disease ascertained by asking whether respondent has ever been told by a doctor or other health professional that they had any of the following conditions: coronary heart disease, angina/angina pectoris, heart attack/myocardial infarction, stroke, or any kind of heart condition or heart disease.

<sup>e</sup> Current smoker was defined as those who had smoked more than 100 cigarettes in their lifetime and now smoke every day or some days.

<sup>f</sup> Physical inactivity was defined as performing <10 min per week of light, moderate, or vigorous leisure-time physical activities.

<sup>g</sup> Excessive alcohol intake was defined as consuming ≥12 drinks in lifetime and >14 drinks/week in past year (for men) or >7 drinks/week in past year (for women).

<sup>h</sup> Obesity was defined as a body mass index >30. Body mass index was calculated, using self-reported data, as weight (in kilograms) divided by height (in meters), squared.

<sup>i</sup> Health conditions were defined as an affirmative response to the question of whether the respondent had ever been told by a doctor or other health professional that they had 1) hypertension or high blood pressure, 2) high cholesterol, or 3) diabetes or sugar diabetes.

**Table 4. Percentage Distribution of Adults by Number of Cardiovascular Disease Risk Factors and Vision Status, Study of Cardiovascular Disease Risk Factors in US Adults With Vision Impairment, 2018**

No. of risk factors	Total prevalence, % (95% CI) <sup>a</sup>	Prevalence by vision status, % (95% CI) <sup>a</sup>	
		Vision impairment	No vision impairment
0	28.0 (27.1–28.9)	16.0 (14.3–17.9)	29.8 (28.9–30.7)
1	29.2 (28.5–30.0)	22.8 (21.0–24.8)	30.2 (29.4–31.0)
2	21.4 (20.7–22.1)	23.9 (22.0–25.9)	21.0 (20.3–21.7)
3	12.7 (12.2–13.2)	19.3 (17.6–21.1)	11.7 (11.2–12.2)
4–7	8.7 (8.3–9.2)	18.0 (16.4–19.7)	7.4 (6.9–7.8)

<sup>a</sup> Because of rounding, weighted percentages may not add up to 100%. Sample size (unweighted) was N = 22,890.

## PROGRAM EVALUATION BRIEF

# Commitment to Hypertension Control During the COVID-19 Pandemic: Million Hearts Initiative Exemplars

Amena Abbas, MPH<sup>1,2</sup>; Judy Hannan, RN, MPH<sup>1</sup>; Haley Stolp, MPH<sup>1,3</sup>;  
Fátima Coronado, MD, MPH<sup>1</sup>; Laurence S. Sperling, MD<sup>1,4</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

The COVID-19 pandemic has caused unprecedented disruptions in routine care and chronic disease management. As hypertension is the most common modifiable risk factor for cardiovascular events, it is imperative that, even during disruptions in care, hypertension control remains a priority.

**What is added by this report?**

In response to the challenges presented by COVID-19, clinicians and health care organizations implemented various and unique strategies to respond to patient needs and expand services to monitor hypertension, demonstrating that even during a time of public health crisis, focus on improving hypertension control is possible.

**What are the implications for public health practice?**

The findings highlight how health care and public health programs have been able to accelerate innovation and adapt services for continuity of care and hypertension control. This may help inform future efforts to improve health care delivery related to hypertension control, during and after a public health emergency.

## Abstract

Hypertension is a major risk factor for cardiovascular diseases, but 3 of 4 US adults do not have their blood pressure adequately controlled. Million Hearts (US Department of Health and Human Services) is a national initiative that promotes a set of priorities and interventions to optimize delivery of evidence-based strategies to manage cardiovascular disease, including hypertension. The

COVID-19 pandemic, however, has disrupted routine care and preventive service delivery. We identified examples of clinical and health organizations that adapted services and care processes to continue a focus on monitoring and controlling hypertension during the pandemic. Eight Hypertension Control Exemplars were identified and interviewed. They reported various adapted care strategies including telemedicine, engaging patients in self-measured blood pressure monitoring, adapting or implementing medication management services, activating partnerships to respond to patient needs or expand services, and implementing unique patient outreach approaches. Documenting these hypertension control strategies can help increase adoption of adaptive approaches during public health emergencies and routine care.

## Introduction

Hypertension is a major risk factor for several chronic diseases, including stroke, heart disease, and other CVDs (1). Blood pressure consistently at or above 130/80 mm Hg is considered hypertensive (1). It is also a significant primary or contributory cause of death in the US (2). Furthermore, estimates indicate that approximately 50% to 75% of adults with hypertension do not have their blood pressure adequately controlled (3).

Infections with SARS-CoV-2, the virus that causes COVID-19, has resulted in approximately 900,000 deaths to date and has had an enormous effect on health and health care in the US (4). In March 2020, shelter-in-place orders went into effect, and states declared a state of emergency as a result of considerable community transmission of COVID-19 (5). Disruptions in routine and non-emergent medical care were reported with substantial decreases in patient visits and restricted hours of operation (6). An estimated 41% of US adults initially avoided or delayed medical care because of COVID-19 concerns or were encouraged to postpone routine appointments with their health care team if determined to be at high risk for COVID-19 (7). Underlying serious health conditions, including hypertension, possibly increase the likelihood of



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severe COVID-19–related illness (8). Thus, it is imperative that, even during disruptions in care, hypertension control remains a priority.

## Purpose and Objectives

Million Hearts (MH), a national initiative to prevent 1 million heart attacks, strokes, and other cardiovascular events within 5 years, focuses the attention of public health and health care partners on a small set of priorities to optimize delivery of evidence-based strategies to achieve specific targets in aspirin use, blood pressure control, cholesterol management, and smoking cessation. Since 2012, the MH Hypertension Control Challenge has recognized clinicians, care practices, and health systems that achieve blood pressure control rates of 70% through 2017 and 80% control through 2019 as Champions (9). The COVID-19 pandemic, however, has disrupted clinical care and preventive service delivery, altered quality improvement support programs, and stalled many public health program activities and initiatives (10). In response to the COVID-19 pandemic, and because of the potential risk of infection during in-person visits, federal agencies relaxed telemedicine regulations and increased funding to support its implementation, which resulted in a substantial increase in the utilization of telemedicine (11). However, the use of patient-generated blood pressure measurements is not uniformly captured in the medical record or universally accepted for reporting data to certain blood pressure control clinical quality measures. Despite these disruptions in care and reporting practices, MH remained committed to recognizing those who continued to address hypertension control. This report identifies and describes lessons learned from clinicians and health care organizations that adapted routine practice or care to maintain a focus on hypertension control during the COVID-19 pandemic.

## Evaluation Methods

MH queried its public and private sector partners to identify Hypertension Control Exemplars. Selection of Exemplars was based on the following criteria: 1) clinicians, medical centers, or health system support organizations that altered patient care or services or implemented new approaches in response to challenges presented by COVID-19 to prioritize hypertension control, 2) uniqueness of intervention, 3) community improvement individuals and organizations that served or prioritized under-resourced or patient populations who were disproportionately affected by COVID-19 or at risk for uncontrolled hypertension, and 4) community improvement individuals and organizations that demonstrated or documented qualitative or quantitative results of their hypertension control efforts and strategies (eg, percentage of patients with hypertension under control, number of patients reached, outcomes of

implemented strategies, other benefits measured). A goal was to identify Exemplars across varied settings, including those delivering clinical care directly and organizations supporting health systems.

In addition to identifying eligible Exemplars, MH staff conducted virtual interviews by using a structured questionnaire to gather qualitative and quantitative data related to hypertension control efforts. The questionnaire gathered information on 1) general demographics and clinical information on the overall patient population and information specific to hypertensive patients, 2) adaptations to routine patient care or health services to monitor and control hypertension, and 3) outcomes and successes of hypertension control strategies, as well as challenges or barriers encountered during implementation. Interviews were audio recorded and transcribed. The Centers for Disease Control and Prevention (CDC) reviewed this study for human subjects' protection and determined it to be nonresearch.

## Results

A total of 8 Hypertension Control Exemplars were identified (Box). Four Exemplars were clinical practices (California Right Meds Collaborative, Community Health & Wellness Partners, Jessie Trice Community Health Center, and Philadelphia FIGHT), including 3 federally qualified health centers that provided direct patient care. Four were health system support organizations (Aledade, Inc, Missouri Hospital Association, Quality Insights, Inc, and YMCA of Central New York). Exemplars providing clinical services served a median population of 7,315 patients, mostly in geographically urban settings (urban service areas). Overall patient characteristics include a 58% racial and ethnic minority mean, 6% with English as second language, 32% with Medicaid coverage, and 26% uninsured. Among Exemplar clinical practices, the mean percentage of patients with a diagnosis of hypertension in 2020 was 31%. The mean blood pressure control rate reported was 65% in 2019, 60% in 2020, and 61% in July 2021. Clinical practices reported a decrease in blood pressure control rates between 2019 and 2020, but an increase or no change between reported rates in 2020 and 2021.

**Box. Million Hearts Hypertension Exemplars and Patient Population Characteristics of Clinical Practices, 2021**

**Practice or medical center**

California Right Meds Collaborative  
Community Health & Wellness Partners  
Jessie Trice Community Health Center

Philadelphia FIGHT

**Health system support organizations**

Aledade Inc.  
Missouri Hospital Association  
Quality Insight Inc  
YMCA of Central New York

**Patient characteristics (Some respondents reported multiple characteristics for patient population. Percentages do not total 100%.)**

Source is HRSA (Health Resources and Services Administration) UDS (Uniform Data System) Database.

**Number of patients** (mean, SD) — 15,000 (18,374.1).

**Racial or Ethnic minority** — 57.9%. Minority status of patients was determined by Exemplars.

**English as second language** — 6.0%

**Enrolled in Medicaid** — 32.1%

**Uninsured** — 25.9%

**Percent with hypertension (mean, SD)** — 30.8% (15.3)

**Hypertension control rates during data collection (mean, SD)**

2019 — 65.0% (9.4%)  
2020 — 60.3% (8.1%)  
2021 — 60.8% (6.9%) is most recent rate available to report in calendar year 2021, June–August

We detailed strategies and reported outcomes for each Exemplar (Table). The average percentage of patients with hypertension that Exemplars reported reaching through their various strategies and interventions was 45%. Exemplars also reported implementing hypertension control strategies that focused on specific characteristics or demographics of patients with hypertension. Exemplars providing clinical services reported using telehealth services, adapting self-measured blood pressure monitoring, establishing drive-thru or parking lot clinics to measure blood pressure, developing medication management strategies, partnering with community organizations, and creating strategies for patient outreach including using population health software to develop high-risk registries for outreach. Several Exemplars reported direct outreach to patients through methods such as delivery of prescription medications to those with comorbidities including hypertension, or phone calls to follow up and assess patient health.

Health system support organizations reported several approaches to respond to critical needs of clinical practices. Approaches included distributing home blood pressure measurement devices, adapting existing program activities to be delivered by using virtual platforms, and leveraging existing partnerships and innovative

payment models to bolster and sustain hypertension activities. The organizations also worked to bolster remote blood pressure monitoring by providing resources to remove barriers or ease bureaucratic challenges for clinical practices to immediately access blood pressure monitoring devices for their patients. Others led efforts to focus on vulnerable patient populations, such as 1 Exemplar that leveraged statewide partnerships to focus on hypertension control among pregnant and postpartum women at highest risk for hypertension-related complications. Health system support organizations also provided resources to identify patients who were at increased risk for adverse cardiovascular events by encouraging participating clinical practices to use dashboards and other analytical software to target patients and monitor trends in blood pressure control.

Several Exemplars reported improved hypertension control rates resulting from supportive practice networks. Examples include a quality improvement network achieving blood pressure control rates of 83%, a medication therapy management pilot achieving a blood pressure control rate of over 85% in previously uncontrolled hypertensive patients, and a pilot delivered in a virtual format that improved control rates from 73% to 82% in its clinical sites in 6 months. Other highlighted outcomes include patient engagement resulting in positive feedback, results from expanded outreach efforts such as medication delivery to more than 600 patients, and blood pressure measurement device distribution. Collectively, Exemplars were successful in distributing over 4,000 devices for self-monitored blood pressure monitoring.

Exemplars reported several challenges and barriers to hypertension control, including limited available funds to meet the demand for blood pressure measurement devices for self-monitored blood pressure monitoring and in bringing public insurance programs to provide blood pressure cuffs to patients. Furthermore, although telehealth services were expanded considerably during the pandemic, many patients were unfamiliar with the technology or had limited access to high-speed internet for stable virtual visits. An ongoing need also exists for flexibility to better streamline processes and workflows to ensure smooth transitions in adapting services throughout the pandemic.

## Implications for Public Health

Our report summarizes hypertension control strategies that MH Exemplars implemented in response to the disruptions to routine medical care during the COVID-19 pandemic. Data support the fact that frequent interactions with clinical staff are essential to chronic disease management and during temporary disruptions in access to health care for hypertensive patients when a natural disaster results in increased rates of uncontrolled hypertension (12).

Identifying innovative strategies and sharing lessons learned from Exemplars might help inform future efforts to improve health care delivery related to hypertension control during and after a public health or environmental emergency.

Patients with existing medical conditions have experienced poor outcomes in the setting of an emergency, including difficulty accessing emergency services and routine care (13). People living with chronic diseases, including hypertension, are at an increased risk of adverse health outcomes in the face of public health emergencies, and this risk increases exponentially with a prolonged crisis (12). Many communities are not adequately prepared to meet the needs of people living with chronic diseases during a public health emergency. MH Exemplars have demonstrated resilience and tenacity in their mission to control hypertension by accelerating innovation and adaptation of their services, despite many challenges through strategies that may have otherwise taken years to integrate into the services and workflow of these clinics and organizations.

Disruptions in access to care as a result of the pandemic have exposed the need to have a more integrated health system with potentially expanded roles for care team members such as community pharmacists. For example, an Exemplar implemented an accelerated pilot program focused on comprehensive medication management using a network of community pharmacists, physicians, and health plans. Studies have demonstrated that pharmacy-delivered medication therapy management can improve health outcomes for hypertensive patients and those with other chronic conditions or comorbidities (14). The medication therapy management program drove collaboration between community pharmacists and primary care physicians, resulting in hypertension control rates of more than 85%.

Many health care organizations and primary care practices used new and adapted existing resources to rapidly move to virtual care. Emergency funds provided by the passage of the CARES (Coronavirus Aid, Relief, and Economic Security) Act were allocated for “provider relief . . . related to expenses or lost revenues that are attributable to coronavirus” (15). Several Exemplars leveraged these emergency funds to immediately respond to the need of their patients and support expenses related to telehealth services, and to provide blood pressure measurement devices, other educational materials, and software for patient care. Moreover, Exemplars demonstrated that existing partnerships facilitated rapid implementation of their interventions and supported ongoing efforts. This activation of a ready network of partners contributed to a rapid response to gaps in care related to COVID-19 for health services and access.

The study is subject to limitations. First, data and outcomes were self-reported. Collecting data on patient outcomes or evaluating changes in blood pressure control rates as a result of the strategies implemented might have been useful. Second, a small number of Exemplars reported strategies focused on specific patient demographics; therefore, we were not able to examine or explicitly address the impact on health disparities. As there are disparities in hypertension control as well as COVID-19 infection and outcomes, it is crucial to document successful strategies for populations at higher risk. Lastly, as the data were obtained from a sample of a small number of clinics and organizations, the results and outcomes are not generalizable to the broader population of hypertension control program partners.

The COVID-19 pandemic has presented many challenges to hypertension control, including unprecedented disruptions to routine care and chronic disease management. The small-scale implementation of comprehensive interventions during a public health crisis allowed Exemplars to demonstrate promising results and sustainable impacts, captured the interest of relevant community members or organizations, and encouraged decision makers and partners to adopt and scale intervention models to their respective health systems. The examples presented demonstrate that even during a time of crisis, focusing on and achieving hypertension control is possible. Many of the adaptations made by these Exemplars can and will continue during noncrises and add important insights into creative solutions to long-standing problems, such as improving hypertension control.

## Acknowledgments

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## Author Information

Corresponding Author: Amena Abbas, MPH, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, 4770 Buford Highway, Mail Stop S107-1, Atlanta, GA 30341. Telephone: (404) 498-5090. Email: aabbas@cdc.gov.

Author Affiliations: <sup>1</sup>Division for Heart Disease and Stroke Prevention, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia. <sup>2</sup>Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee. <sup>3</sup>ASRT Inc., Atlanta, Georgia. <sup>4</sup>Department of Medicine, Division of Cardiology, Emory University School of Medicine, Atlanta, Georgia.

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Table

**Table. Strategies and Outcomes by Hypertension Control Exemplars in Implementing Hypertension Control Strategies in Response to COVID-19**

Exemplar	Modifications to routine practice or care for blood pressure control during COVID-19	Reported outcomes
<b>Clinical practice or health center</b>		
California Right Meds Collaborative	<ul style="list-style-type: none"> <li>• Piloted program to utilize community pharmacy network to deliver comprehensive medication management services</li> <li>• Trained pharmacists to provide video and phone telehealth services</li> <li>• Developed registry for outreach to high-risk beneficiaries of participating health plans</li> <li>• Facilitated access to home blood pressure monitors, either through health plan or provided by pharmacy</li> </ul>	<ul style="list-style-type: none"> <li>• Reduced systolic blood pressure of hypertensive patients by 23 mm Hg</li> <li>• Achieved blood pressure control rate of more than 85% in previously uncontrolled hypertensive patients</li> </ul>
Community Health & Wellness Partners	<ul style="list-style-type: none"> <li>• Program care coordinator messaged patients twice a week to check in on health of patients and promote awareness of telehealth services</li> <li>• High-risk patients enrolled by telephone into their chronic care management program</li> <li>• Used onsite parking lot to serve patients</li> <li>• Hypertensive enrollees received text messages with information about DASH and blood pressure management</li> <li>• Clinical pharmacist used telehealth video feed to cover other practice locations and increase reach to patients</li> </ul>	<ul style="list-style-type: none"> <li>• Converted approximately 12% of cold messages from a nurse into active patients</li> <li>• 97% of patients respond to a message</li> <li>• In evaluating service, 91% of patients rated the new adapted services at least a 9 out of 10</li> </ul>
Jessie Trice Community Health Center	<ul style="list-style-type: none"> <li>• Established a drive-through clinic where chronic care patients could get their blood pressure measured (and hemoglobin A1c tested)</li> <li>• Self-monitored blood pressure platform that used cellular data to remotely monitor chronic care patients</li> <li>• Used readings and data transmitted back to adjust the patient's medication or request an in-person visit to the office if needed</li> <li>• Provided virtual meetings and classes with behavioral health, nutritionists, and medicine management specialists to speak to patients</li> </ul>	<ul style="list-style-type: none"> <li>• 900 patients received home blood pressure measurement device, 1,055 blood pressure screenings</li> <li>• Enrolled 72 in remote monitoring through Bluetooth and 110 self-monitored; reported measures during follow-up (onsite or telehealth visit)</li> </ul>
Philadelphia FIGHT	<ul style="list-style-type: none"> <li>• Established hotline to health centers to have live health care available to patients</li> <li>• Delivered medications to patients unable to receive at-home delivery through pharmacy</li> <li>• Identified high risk patients with chronic conditions for direct outreach</li> <li>• Provided phone instruction to patients on how to accurately use at-home blood pressure measurement devices</li> </ul>	<ul style="list-style-type: none"> <li>• Reached more than 5,000 patients</li> <li>• Delivered medication to 600 patients</li> <li>• Provided medication management support to 1,200 patients</li> </ul>
<b>Health system support or community health organization</b>		
Aledade Inc	<ul style="list-style-type: none"> <li>• Transformed AMA MAP program to virtual pilot</li> <li>• Created dashboards to monitor trends in blood pressure control and dashboard with the list of uncontrolled patients</li> <li>• Distributed blood pressure kits to expand self-monitored blood pressure services</li> <li>• Collected blood pressure monitoring data from participating clinics - disseminated results to increase awareness and outreach to populations at increased risk for uncontrolled hypertension</li> <li>• Trained staff at pilot sites on how to bill for telehealth services</li> </ul>	<ul style="list-style-type: none"> <li>• Successfully scaled pilot to 3 sites covering approximately 7,000 patients</li> <li>• Improved blood pressure control rate from 73% to 82% within 6 months</li> <li>• Expanded program in virtual format to remaining sites (total 30)</li> </ul>
Missouri Hospital Association	<ul style="list-style-type: none"> <li>• Provided pregnant and postpartum women at highest risk for a hypertension-related complication a home blood pressure measurement device</li> <li>• Worked with established programs to get blood pressure devices to a network of hospitals and clinicians</li> <li>• Focus support on cardiovascular complications related to pregnancy</li> <li>• Provided educational materials on hypertension management and amplified telehealth for hypertension treatment</li> </ul>	<ul style="list-style-type: none"> <li>• 3,000 blood pressure cuffs distributed to 35 sites in Missouri</li> </ul>

Abbreviations: AMA MAP, American Medical Association Measure Accurately, Act Rapidly, Partner With Patients; blood pressure, blood pressure; DASH, Dietary Approaches to Stop Hypertension; self-measured blood pressure monitoring.

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(continued)

**Table. Strategies and Outcomes by Hypertension Control Exemplars in Implementing Hypertension Control Strategies in Response to COVID-19**

Exemplar	Modifications to routine practice or care for blood pressure control during COVID-19	Reported outcomes
Quality Insights, Inc.	<ul style="list-style-type: none"> <li>• Adapted quality improvement approach to continue supporting network of practices during COVID</li> <li>• Assisted participating clinics to adjust to telehealth and modified workflows</li> <li>• Provided technical assistance to participating health care organizations by shifting site visits to virtual visits and meetings</li> <li>• Assisted clinics in accessing blood pressure kits by providing resources and guidance in working with insurance companies</li> <li>• Partnered with pharmacists to work with physicians on medication management therapy</li> </ul>	<ul style="list-style-type: none"> <li>• Supported participating practices to achieve blood pressure control rate of 83%</li> <li>• Worked with 50 pharmacists for medication management services</li> </ul>
YMCA of Central New York	<ul style="list-style-type: none"> <li>• Established 16-week employer-based hypertension control and lifestyle modification program</li> <li>• Assisted and coached in use of home blood pressure monitors and lifestyle modification through virtual one-to-one office hours</li> <li>• Discussed blood pressure readings during office hours (eg, stressors, adherence to diets, exercise)</li> <li>• Offered virtual classes and peer support to participants</li> </ul>	<ul style="list-style-type: none"> <li>• Virtual format increased participant engagement</li> <li>• Participants reported high satisfaction with program</li> </ul>

Abbreviations: AMA MAP, American Medical Association Measure Accurately, Act Rapidly, Partner With Patients; blood pressure, blood pressure; DASH, Dietary Approaches to Stop Hypertension; self-measured blood pressure monitoring.

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GIS SNAPSHOTS

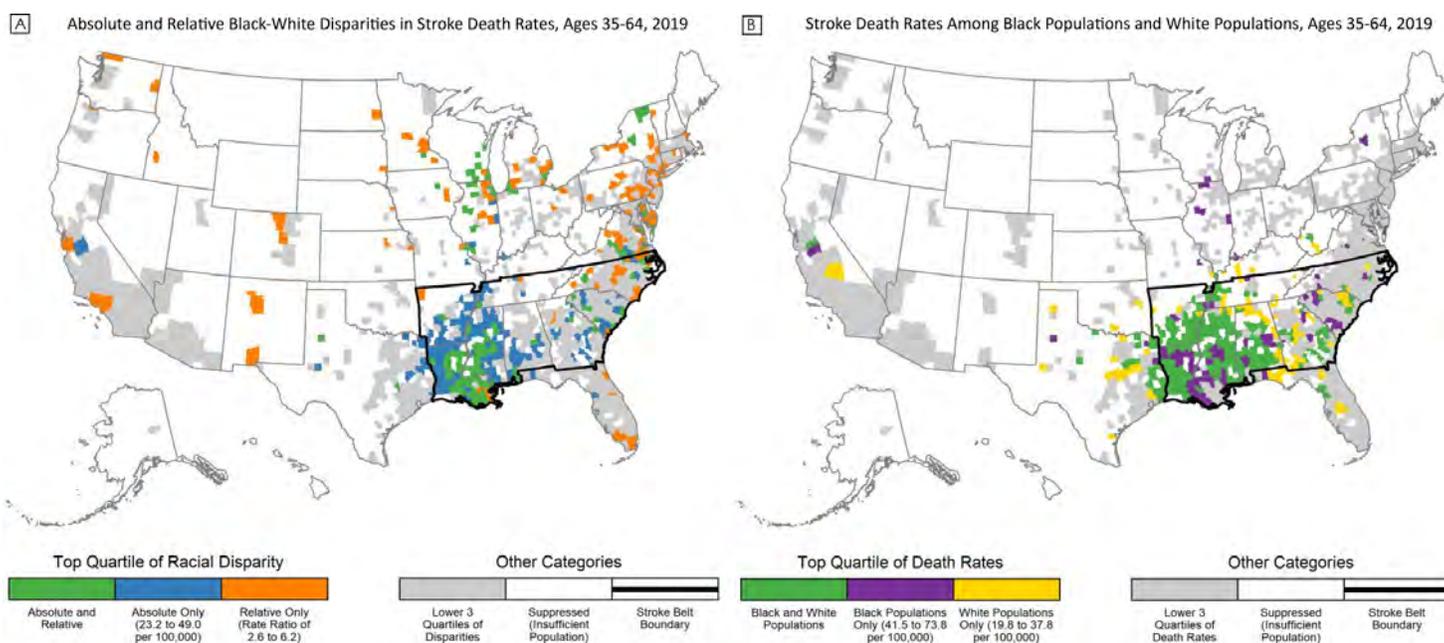
# Differences in Geographic Patterns of Absolute and Relative Black–White Disparities in Stroke Mortality in the United States

Aspen Flynn, MPH<sup>1</sup>; Adam S. Vaughan, PhD, MPH, MS<sup>1</sup>; Michele Casper, PhD<sup>1</sup>

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PEER REVIEWED



Source: Modeled estimates of data from the National Vital Statistics System of the National Center for Health Statistics

Absolute and relative Black–White disparities in stroke death rates for people aged 35 to 64 years, 2019 (Map A), and stroke death rates for Black populations and White populations for people aged 35 to 64 years, 2019 (Map B). Source: National Center for Health Statistics.



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## Background

In the US, racial disparities in stroke death rates are particularly large among working age adults, for whom the stroke death rate in 2019 among non-Hispanic Black adults aged 35 to 64 years was 2.4 times that of their non-Hispanic White counterparts (1,2). These national disparities occur in the context of marked local variation in stroke death rates among both Black and White populations. Within the Stroke Belt (a band of southern US states with high stroke mortality), stroke death rates for both Black and White populations are persistently high (3). However, county-level racial disparities in stroke death rates have not been documented. These data are critical to addressing racial inequities in stroke mortality by shaping public health agendas, engaging communities, and guiding prioritization and development of programs, interventions, and policies (2,4). Therefore, we calculated race-specific stroke death rates in 2019 for adults aged 35 to 64 years and mapped the geographic variation of the largest absolute and relative Black–White disparities in stroke death rates (Map A) and of the highest stroke death rates for Black populations and White populations (Map B).

## Data and Methods

We obtained stroke death counts (International Classification of Diseases, 10th revision codes I60-I69) and total population for people aged 35 to 64 years by county of residence for 2019 from the National Vital Statistics System of the National Center for Health Statistics (5,6). We used a Bayesian conditional autoregressive model to estimate county-level stroke death rates for non-Hispanic Black and White populations aged 35 to 64 years in 2019 (7). This model smooths data across neighboring counties to generate reliable, precise estimates of county-level death rates, even for counties with small populations (7,8). Using these rates, we calculated absolute and relative Black–White stroke mortality disparities for each county. We then mapped the counties in the top quartile for race-specific stroke death rates and Black–White stroke mortality disparities. For a county to be included in this analysis, we required that, for both Black and White populations, the estimated stroke death rate be reliable (ie, the rate's precision as defined by the width of the 95% credible interval was less than the point estimate) and the population was greater than 1,000 in 2019. These requirements ensured that we only reported reliable heart disease death rates for sufficiently large populations. All rates were age-standardized to the 2010 US population. We used R version 4.1.1 for data analysis and map creation (9).

## Highlights

The largest absolute and relative Black–White disparities in stroke death rates among adults aged 35 to 64 years had different and opposing county-level geographic patterns (Map A). Counties in the top quartile of absolute Black-White disparities (rate difference 23.2 to 49.0 deaths per 100,000 population) were concentrated in the South in the well-established Stroke Belt, where stroke death rates were high for both Black and White populations. Counties in the top quartile of relative disparities (rate ratio 2.6 to 6.2) were scattered across the mid-Atlantic, Northeast, and Great Lakes region. Counties in the top quartile for both absolute and relative disparities were located primarily in the Mississippi Delta region. Counties in the top quartile of stroke death rates for both Black and White populations were concentrated in the South, primarily Louisiana, the Mississippi Delta region, and western Alabama (Map B).

The similarity of geographic patterns for large absolute Black–White disparities and high race-specific stroke death rates (both concentrated in the Stroke Belt) stems from the calculation of absolute disparities. Given the presence of high stroke death rates for both Black populations and White populations in the Stroke Belt (Appendix), the absolute difference in rates must, by definition, be higher in this region (Appendix). In contrast, the largest relative Black–White disparities occurred primarily in counties with lower stroke death rates. A majority of the counties with large relative disparities (64.1%) are located outside the Stroke Belt. Mimicking the geographic pattern of counties with high stroke death rates for both Black populations and White populations, counties in Mississippi and Louisiana are in the top quartile of both absolute and relative disparities.

## Action

The markedly different geographic patterns of absolute and relative Black–White disparities in stroke mortality among adults aged 35 to 64 years demonstrate the importance of examining both measures of disparities, along with race-specific rates, when prioritizing efforts to eliminate racial inequities in stroke mortality. Absolute and relative disparity measures provide different, but complementary, documentation necessary to fully address racial inequities in stroke mortality (10). Large absolute disparities highlight areas with high underlying race-specific stroke death rates, whereas large relative disparities draw attention to areas where race-specific death rates may be lower but inequities are still large.

Racial inequities are most commonly measured as relative disparities (11). For stroke mortality, the observation that counties with the largest relative Black–White disparities tend to have lower race-specific stroke death rates suggests that the conditions contributing to lower rates are not extended equitably across racial groups. Using only relative disparity as the basis for programs and policies focused on eliminating Black–White disparities in stroke mortality, however, would miss many counties in the Stroke Belt where stroke death rates are high for both Black populations and White populations. Conversely, using only absolute disparity as the metric for efforts to eliminate Black–White inequities in stroke mortality would miss many communities outside the Stroke Belt with lower stroke death rates yet substantial excess mortality among Black populations. Finally, programs and policies that focus on areas with large disparities in both relative and absolute terms will reach a smaller, albeit important, subset of counties.

## Author Information

Corresponding Author: Michele Casper, PhD, Division for Heart Disease and Stroke Prevention, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, 4770 Buford Hwy, Atlanta, GA, 30341. Telephone: 770-488-2571. Email: myc5@cdc.gov.

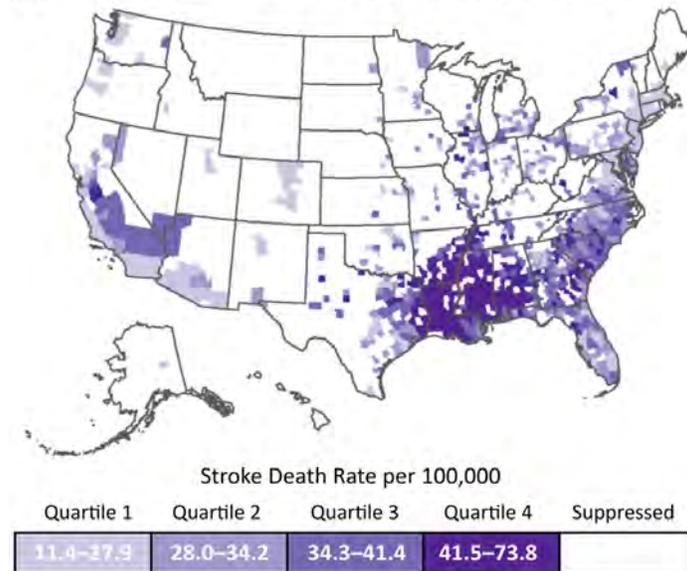
Author Affiliations: <sup>1</sup>Division for Heart Disease and Stroke Prevention, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia.

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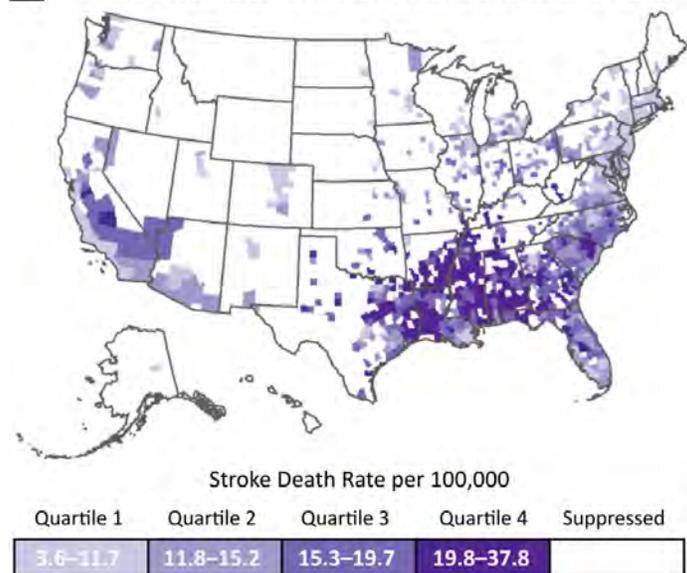
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**Appendix. County-level race-specific stroke death rates per 100,000 for Black populations and White populations aged 35 to 64 years, 2019**

**A** Stroke Death Rates for Black Populations, Ages 35–64, 2019



**B** Stroke Death Rates for White Populations, Ages 35–64, 2019



Map A shows county-level stroke death rates for Black populations aged 35 to 64 years, and Map B shows county-level stroke death rates for White populations aged 35 to 64 years. Quartile cutpoints are based on the race-specific distributions of stroke death rates per 100,000 population. Only counties that met the inclusion criteria for the study are included on the maps.

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## ORIGINAL RESEARCH

# Cigarette Smoking Among US Adults With Selected Chronic Diseases Associated With Smoking, 2010–2019

Caitlin G. Loretan, MPH<sup>1</sup>; Monica E. Cornelius, PhD<sup>1</sup>; Ahmed Jamal, MBBS<sup>1</sup>; Yiling J. Cheng, PhD<sup>1</sup>; David M. Homa, PhD<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

Cigarette smoking has been linked to more than 27 diseases, including respiratory and cardiovascular diseases, cancers, and diabetes.

**What is added by this report?**

In 2019, more than 1 in 4 US adults aged 18 to 64 years with at least 1 chronic disease associated with smoking reported that they currently smoke. During 2010 through 2019, the only significant decrease in cigarette smoking was found among adults aged 65 years or older living with diabetes.

**What are the implications for public health practice?**

The findings of this report may help identify groups of people who continue to smoke and could potentially benefit from access, promotion, and integration of cessation treatment across the continuum of health care.

## Abstract

**Introduction**

People who smoke cigarettes are at greater risk of developing chronic diseases and related complications. Our study provides recent estimates and trends in cigarette smoking among people with respiratory and cardiovascular diseases, cancers, and diabetes.

**Methods**

Using data from the 2019 National Health Interview Survey, we calculated the prevalence of current and former cigarette smoking

among adults aged 18 to 44 years, 45 to 64 years, and 65 years or older with chronic diseases. Those diseases were cancers associated with smoking, chronic obstructive pulmonary disease, diabetes, coronary heart disease, and/or stroke (N = 3,741). Using data from the 2010–2019 National Health Interview Surveys, we assessed trends in current cigarette smoking by chronic disease by using the National Cancer Institute's Joinpoint Regression Program.

**Results**

In 2019, current cigarette smoking prevalence among adults with chronic diseases associated with smoking ranged from 6.0% among adults aged 65 or older with diabetes to 51.9% among adults aged 18 to 44 years with 2 or more chronic diseases. During 2010 through 2019, a significant decrease occurred in current cigarette smoking among adults aged 45 to 64 years with diabetes.

**Conclusion**

Overall, smoking prevalence remains high and relatively unchanged among people with chronic diseases associated with smoking, even as the overall prevalence of cigarette smoking in the US continues to decrease. The lack of progress in smoking cessation among adults with chronic diseases associated with smoking suggests that access, promotion, and integration of cessation treatment across the continuum of health care (ie, oncology, pulmonology, and cardiology settings) may be important in the success of smoking cessation in this population.

## Introduction

Chronic diseases associated with cigarette smoking include respiratory and cardiovascular diseases, cancers, and diabetes (1). An estimated 16 million US adults live with a smoking-related disease (1). Cigarette smoking can increase the risk of chronic dis-



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ease and subsequent complications and can lead to overall reduced quality of life (1). As of 2019, 34.1 million adults (14.0%) in the US currently smoke cigarettes (2).

Cigarette smoking is the predominant cause of lung cancer and chronic obstructive pulmonary disease (COPD). Furthermore, smoking increases one's risk of cardiovascular disease, several types of cancer, diabetes, and other chronic conditions (1,3–6). Although many studies have evaluated the effect of smoking on chronic disease development, few studies have assessed the prevalence of current cigarette smoking among adults with chronic diseases. The most recent published estimates of cigarette smoking among adults with asthma, diabetes, heart disease, hypertension, hepatitis, HIV, lung cancer, or stroke were reported using data from the 2013 National Survey on Drug Use and Health (7).

The objectives of our study were to 1) provide the most recent (2019) estimates of current and former cigarette smoking among adults aged 18 years or older with chronic diseases that can be associated with smoking (hereinafter, chronic disease) and 2) report temporal changes in current cigarette smoking among adults with chronic disease during 2010 through 2019.

## Methods

### Study sample

We obtained data from the 2010–2019 National Health Interview Surveys (NHIS) to examine self-reported cigarette smoking behaviors among adults aged 18 years or older with chronic disease. We chose to include adults aged 18 years or older on the basis of prior research related to the prevalence of multiple chronic diseases (8). The NHIS is an annual, nationally representative, cross-sectional, household survey of the noninstitutionalized US civilian population that has previously been described in detail (9). In 2019, NHIS underwent changes to nonresponse survey weighting methodology and questionnaire redesign (10,11). Respondents with unreported age and missing cigarette smoking status were excluded ( $n = 878$ ). Our analyses were conducted during 2020 through 2022. During 2010 through 2019, survey response rates for sample adults aged 18 years or older ranged from 53.0% in 2017 to 63.3% in 2011 (9,12).

### Measures

Current cigarette smoking was defined as a person having smoked 100 or more cigarettes in their lifetime and smoking every day or some days at the time of interview (2). Former cigarette smoking was defined as a person having smoked 100 or more cigarettes in their lifetime and not smoking at all at the time of interview.

### Chronic disease

Chronic diseases were assessed by self-report, asking participants if they had ever been diagnosed with any 1 of the 5 selected chronic diseases, or 2 or more. Chronic diseases were cancer (bladder, cervix, colorectal, esophagus, kidney, larynx, liver, lung, oropharynx, pancreas, stomach, trachea); COPD (emphysema, chronic bronchitis); diabetes; coronary heart disease (CHD); and stroke (1). Participants were included in the analysis as having a chronic disease if they answered yes to “Have you ever been told by a doctor or other health professional that you had [disease]?”, apart from CHD and COPD.

### CHD and myocardial infarction (MI)

Separate questions were asked for CHD or heart attack and MI, an outcome of CHD. Respondents were coded as having CHD if they answered yes to having been told they had CHD or if they answered yes to having been told they had a MI, regardless of their response for CHD.

### COPD

For COPD, participants were considered to have COPD if they answered yes when asked if they had ever been told by a doctor or other health professional that they had chronic obstructive pulmonary disease, also called COPD, 2) if they have ever been told by a doctor or other health professional that they had emphysema, or 3) if during the past 12 months they were told by a doctor or other health professional that they had chronic bronchitis.

### Two or more chronic diseases

Participants were included as having 2 or more chronic diseases if they reported more than 1 of the aforementioned chronic diseases assessed in this study. Disease categories were not mutually exclusive.

NHIS questions did not allow us to distinguish between type 1 and type 2 diabetes, although cigarette smoking increases the risk of developing type 2 diabetes (1). Data on kidney cancer was not accessible for 2019. Our analysis excluded acute myeloid leukemia because NHIS does not differentiate between leukemia and acute myeloid leukemia.

### Statistical analysis

We used 2019 NHIS data to calculate prevalence estimates and 95% CIs for current and former cigarette smoking among adults with chronic disease. We reported the prevalence of cigarette smoking by chronic disease for the following age groups: 18 to 44 years (young), 45 to 64 years (middle-aged), and 65 or older (older) (8).

We calculated the annual percentage change (APC) of current cigarette smoking from 2010 to 2019 for each chronic disease by age group using the National Cancer Institute's Joinpoint Regression Program version 4.8.01 (SEER\*Stat), which uses log-linear models and a Monte Carlo permutation test for significant changes in trend (13). Identification of a joinpoint at a given year indicates a significant change in trend. In the absence of joinpoints, APCs were considered constant and equal to average APC, which is a summary measure of APCs over a period of time (14). Significance was defined as  $P < .05$  for trends. To calculate prevalence estimates, we first used variance estimation variables to account for the multistage complex sampling design of the survey. Data were then weighted to provide nationally representative estimates. In accordance with the 2017 National Center for Health Statistics guidelines, statistically unreliable estimates were suppressed (15). Analyses were conducted using SAS-callable SUDAAN software version 11.0.3 (RTI International).

## Results

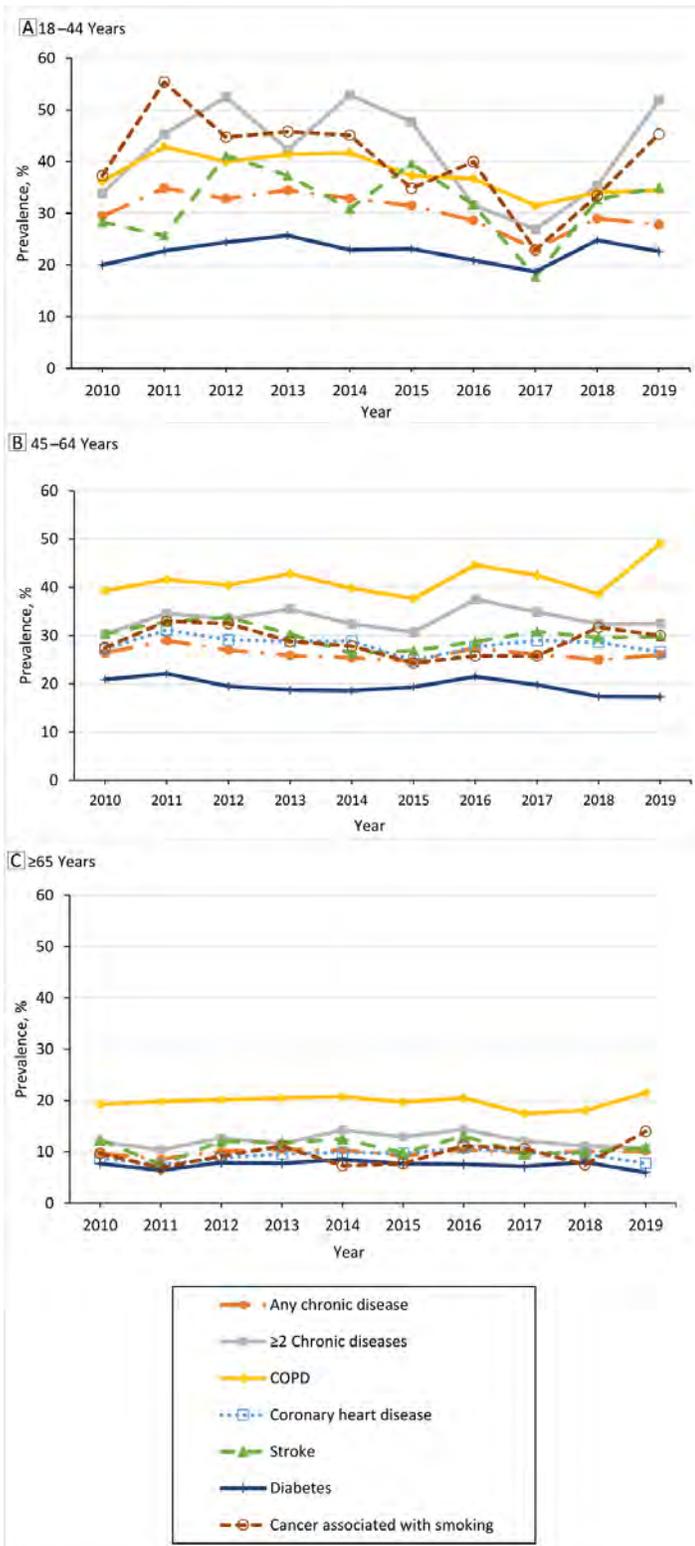
In 2019, the unweighted NHIS sample contained 31,997 adults; of these, 3,741 (11.7%) reported current or former cigarette smoking and any chronic disease. Of these 3,741 participants, 262 (7.0%) were aged 18 to 44 years, 1,305 (34.9%) were aged 45 to 64 years, and 2,174 (58.1%) were aged 65 years or older.

Current cigarette smoking prevalence among young adults in the study ranged from 22.6% (95% CI, 16.4%–28.8%) among those with diabetes to 51.9% (95% CI, 37.4%–66.5%) among those with 2 or more chronic diseases (Table 1). Among the middle-aged group, current cigarette smoking prevalence ranged from 17.3% (95% CI, 15.0%–19.7%) among those with diabetes to 49.1% (95% CI, 44.2%–53.9%) among those with COPD. Among the older age group, current cigarette smoking prevalence ranged from 6.0% (95% CI, 4.7%–7.4%) among those with diabetes to 21.5% (95% CI, 18.4%–24.5%) among those with COPD.

Among young adults, the prevalence of former cigarette smoking ranged from 13.6% (95% CI, 10.6%–16.6%) among those with any chronic disease to 20.0% (95% CI, 9.0%–31.0%) among those with 2 or more chronic diseases (Table 1). Among middle-aged adults, the prevalence of former cigarette smoking ranged from 24.7% (95% CI, 19.3%–30.2%) among those with a history of stroke to 34.2% (95% CI, 26.0%–42.4%) among those with history of cancer. Among older adults, prevalence ranged from 42.8% (95% CI, 39.9%–45.8%) among those with diabetes to 57.6% (95% CI, 54.1%–61.1%) among those with COPD.

During 2010 through 2019, adults aged 45 to 64 years and those older than 65 years with COPD consistently had a high prevalence of current cigarette smoking (Figure). Among older adults

with CHD, the prevalence of current cigarette smoking significantly increased during 2010 to 2016, then began trending downward. Additionally, among older adults with 2 or more chronic diseases, the trend in the prevalence of current cigarette smoking increased during 2010 to 2016, then decreased (Table 2). We did not find other joinpoints; therefore, all other APCs were considered constant and equal to average APC. We found a significant decrease in current cigarette smoking among middle-aged adults with diabetes.



**Figure.** Trends in prevalence of current cigarette smoking by age group and chronic disease associated with cigarette smoking, National Health Interview Survey, 2010–2019. A, Participants aged 18 to 44 years. B, Participants aged 45 to 64 years. C, Participants aged 65 years or older. Abbreviation: NR, not reported.

## Discussion

This study found that cigarette smoking persists among adults with chronic disease. Cigarette smoking is most prevalent among young and middle-aged adults and among adults with a history of COPD and 2 or more chronic diseases. Cigarette smoking prevalence among middle-aged adults with diabetes decreased during 2010 through 2019.

In 2019, among adults with COPD, at least 1 in 5 participants reported current cigarette smoking. Several characteristics might make it harder for people with COPD to quit smoking. Some studies have found that people with COPD who continue to smoke may have greater nicotine dependency and smoke more cigarettes per day; inhale a greater volume of smoke, allowing for increased amounts of substances into the lungs; or might not have the self-esteem and motivation to eventually achieve smoking cessation (16,17). More than 1 in 3 young adults and almost 1 in 2 middle-aged adults with COPD reported cigarette smoking. This is an important finding because smoking cessation is the only established intervention that reduces loss of lung function among people with COPD, and the sooner a person quits smoking, the slower the rate of decline in lung function (18). These results are comparable to previous findings and are not surprising given that smoking is the dominant cause of COPD (16,19).

In our study we found that more than 1 in 4 adults aged 45 to 64 years with CHD currently smoked cigarettes. We did not find any significant temporal change in current cigarette smoking among adults with CHD. The association between smoking and cardiovascular disease is well established, with even low levels of cigarette exposure implicated in acute cardiovascular events, such as MI (1). A study reported that 52.5% of patients (median age 45 years) hospitalized with acute MI were currently smoking cigarettes, and 62.0% of those who smoked at the time of their MI continued to smoke after the event (20). Another study showed that adults who experienced a recent MI increased perception of the harm of smoking continuation and were more likely to report that they were attempting to reduce their smoking consumption or quit (21). However, there was no association between recent MI and smoking cessation (21). Results from earlier research using data from 2005 to 2013 reported increased prevalence of cigarette smoking among adults with heart disease and hypertension com-

pared to adults without chronic disease (7). Additionally, a study using a large US registry found that only 1 in 3 adults who smoke cigarettes and were seen for a cardiology visit received smoking cessation services (22).

The prevalence of cigarette smoking among survivors of cancers associated with smoking reported in this study is higher than NHIS-based estimates of cigarette smoking among all cancer survivors reported by the National Cancer Institute (23). One possible explanation for our higher estimates is our restriction of cancer types to those that are causally associated with cigarette smoking. Similar to our findings, the National Cancer Institute reported a decrease in cigarette smoking with increasing age among all cancer survivors (23). Regardless of age and cancer type, it is important for all cancer survivors to quit smoking, because evidence suggests that smoking cessation has the potential to decrease all-cause mortality among all cancer survivors (18).

Current cigarette smoking can complicate treatment of diabetes and lead to increased risk of cardiovascular disease, kidney disease, reduced circulation, and loss of sight (1). Notably, we found a significant decrease in cigarette smoking among middle-aged adults with diabetes over time. A 2015 study reported that among people with type 2 diabetes, many did not realize that cigarette smoking was a causative risk factor for type 2 diabetes (24). Our results reinforce the importance of knowledge and education with respect to smoking cessation. We did not see the significant changes in cigarette smoking among adults with diabetes in the young or older age groups, but this could be partially explained by more yearly type 2 diabetes incidence among middle-aged adults (25).

More than 1 in 3 young and middle-aged adults with 2 or more chronic diseases report current cigarette smoking. People who smoke cigarettes and have multiple chronic diseases appear to seek health care services more frequently and are more likely to try to quit with the support of evidence-based cessation treatments such as nicotine replacement therapy (26), yet the increased number of quit attempts and use of evidence-based cessation methods did not appear to equate to increased smoking cessation success (26). Viewing cigarette smoking as a chronic disease and, therefore, using chronic disease management methods for smoking cessation might help adults achieve smoking cessation (26). The use of these methods has been associated with both short-term and long-term smoking cessation versus usual care (27).

Young and middle-aged adults with chronic disease consistently had a prevalence of current cigarette smoking that was higher than the prevalence among older adults. In many cases, estimates were more than double. These findings have several possible explanations. Overall, cigarette smoking prevalence tends to be higher

among young age groups, regardless of chronic disease status (2). Another possible explanation is a lower prevalence of traditional risk factors (eg, hypertension, hyperlipidemia) for chronic disease among young populations that typically lead to the development of chronic disease in older populations (20). Therefore, because of the low prevalence of these risk factors among young populations, smoking is more likely to be a primary risk factor for chronic disease in young populations (20). Additionally, the health effects of smoking are cumulative. Therefore, right censoring caused by increased likelihood of overall mortality among older populations may be a contributing factor in these findings. Additionally, age disparities in cigarette smoking may result from fewer visits to health care professionals, lack of tobacco use assessments, or low levels of tobacco cessation counseling among young adults who smoke cigarettes (18). The prevalence of tobacco counseling during outpatient visits has been previously reported as 14.5% among adults aged 18 to 24 years, compared with 22.1% among adults aged 45 to 64 years (18). Frequency of cessation advice provided by health care professionals has increased since 2000 (18). Yet almost 1 in 3 adults who smoke and have a chronic disease associated with smoking are not receiving advice to quit during their annual health care visits (18). Further research examining cessation rates among adults with chronic disease may further contextualize the findings of this report.

Approximately 1 in 4 young and middle-aged adults with COPD, CHD, stroke, diabetes, cancer associated with smoking, or people with 2 or more of these chronic diseases report current cigarette smoking. Smoking cessation can reduce morbidity and mortality risk in these populations. Using evidence-based cessation treatments, health care professionals can support the estimated 72.7% of adults aged 25 to 44 years and 68.7% of adults aged 45 to 64 years who report an interest in quitting (9,28). By quitting smoking, individuals with CHD can reduce their overall risk of mortality and risk of a new cardiac event, and disease and symptom progression of COPD can be slowed (18). Cancer survivors can improve their overall prognosis and might have the potential to decrease their mortality risk by quitting smoking (1,18,29). The results of this study indicate a need to provide appropriate smoking cessation services at the right time and in the right setting to adults living with chronic diseases. In addition, public health can help work toward reducing smoking among adults with chronic disease by continuing outreach of representative campaigns, such as Tips from Former Smokers, a Centers for Disease Control and Prevention media campaign that has frequently included people with cancer, COPD, CHD, and diabetes.

## Limitations

Several limitations apply to this study. First, cigarette smoking status and health outcomes were self-reported, resulting in potential recall and social desirability bias. Second, temporality of smoking initiation among those who currently smoke and quitting among those who formerly smoked cigarettes is unknown. Third, we were unable to distinguish type 1 and type 2 diabetes in the survey and could look at only those chronic diseases assessed in NHIS (eg, reason for exclusion of acute myeloid leukemia). Fourth, NHIS underwent changes to the nonresponse adjustment to sample weighting and a questionnaire redesign in 2019 (11), so comparisons using 2019 data must be interpreted with caution. Lastly, while this study provides evidence of an opportunity to improve clinical cessation services among adults with chronic disease, smoking is not always captured in clinical data (ie, electronic health records) and, therefore, might lead to a missed opportunity to provide cessation services. Even if smoking information is captured in clinical data, that information is not always used.

## Conclusions

Our study provides updated estimates of current and former cigarette smoking among adults aged 18 years or older with chronic diseases associated with cigarette smoking. This study also provides new information on cigarette smoking trends among adults with chronic diseases over a 10-year period. Only one significant decrease in cigarette smoking was reported among age groups with chronic diseases over the past 10 years (middle-aged adults with diabetes), relative to the overall decrease in smoking prevalence seen among all US adults (2). The results of this study indicate a consistent prevalence of cigarette smoking and a lack of progress over time in smoking reduction in these populations, who, in addition, are at risk of further complications by continuing to smoke. Cessation advice and services are not being provided to almost 1 in 3 people who have a chronic disease (18). Greater access to cessation services, integration of cessation treatment into routine care in all clinical settings, recognition that people who smoke might benefit from a chronic disease–type management model, and long-term follow up and support may be important steps to take toward successful smoking cessation in this population (29).

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## Author Information

Corresponding Author: Caitlin Loretan, MPH, Office on Smoking and Health, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, 4770 Buford Hwy, MS S107-7, Atlanta, GA 30341. Email: [cloretan@cdc.gov](mailto:cloretan@cdc.gov).

Author Affiliations: <sup>1</sup>Office on Smoking and Health, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention, Atlanta, Georgia.

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Tables

**Table 1. Prevalence of Cigarette Smoking by Chronic Disease Associated With Smoking Among Adults Aged ≥18 Years, National Health Interview Survey, US, 2019**

Chronic disease, by age group	Current cigarette smoking, <sup>a</sup> % (95% CI)	Former cigarette smoking, % (95% CI)
<b>Aged 18–44 y</b>		
Any chronic disease <sup>b</sup>	27.8 (23.3–32.3)	13.6 (10.6–16.6)
Chronic obstructive pulmonary disease	34.5 (25.5–43.4)	18.8 (11.5–26.2)
Coronary heart disease	34.4 (22.2–46.7)	NR
Stroke	35.0 (23.1–46.8)	NR
Diabetes	22.6 (16.4–28.8)	14.5 (10.1–19.0)
Cancer associated with smoking <sup>c</sup>	45.3 (31.8–58.8)	NR
≥2 Chronic diseases	51.9 (37.4–66.5)	20.0 (9.0–31.0)
<b>Aged 45–64 y</b>		
Any chronic disease <sup>b</sup>	26.0 (23.9–28.1)	28.2 (25.9–30.5)
Chronic obstructive pulmonary disease	49.1 (44.2–53.9)	32.5 (28.2–36.9)
Coronary heart disease	26.6 (22.5–30.6)	32.0 (27.6–36.4)
Stroke	29.8 (22.8–36.8)	24.7 (19.3–30.2)
Diabetes	17.3 (15.0–19.7)	27.9 (25.0–30.8)
Cancer associated with smoking <sup>c</sup>	30.0 (22.5–37.4)	34.2 (26.0–42.4)
≥2 Chronic diseases	32.5 (27.8–37.1)	32.1 (27.6–36.7)
<b>Aged ≥65 y</b>		
Any chronic disease <sup>b</sup>	10.1 (9.0–11.3)	45.9 (44.0–47.7)
Chronic obstructive pulmonary disease	21.5 (18.4–24.5)	57.6 (54.1–61.1)
Coronary heart disease	7.8 (6.1–9.5)	51.3 (48.4–54.3)
Stroke	10.8 (7.8–13.7)	46.6 (42.5–50.7)
Diabetes	6.0 (4.7–7.4)	42.8 (39.9–45.8)
Cancer associated with smoking <sup>c</sup>	14.0 (10.1–17.9)	48.5 (43.1–53.8)
≥2 Chronic diseases	10.7 (8.6–12.9)	53.9 (50.4–57.3)

Abbreviation: NR, not reported.

<sup>a</sup> Currently, daily, or some days of cigarette smoking at the time of survey.

<sup>b</sup> Chronic disease includes any of the following associated with smoking: chronic obstructive pulmonary disease, coronary heart disease, stroke, diabetes, and cancer associated with smoking.

<sup>c</sup> Bladder, cervical, colorectal, esophageal, kidney, larynx or trachea, liver, lung, oropharynx, pancreas, and stomach cancers. Data for kidney cancer were not accessible for 2019.

**Table 2. Trends in Current Cigarette Smoking by Age Group and Chronic Disease in the US, National Health Interview Survey, 2010–2019**

Chronic disease, by age group	Current cigarette smoking <sup>a</sup>	
	Annual percentage change <sup>b</sup> (95% CI)	P value
<b>Aged 18–44 y</b>		
Any chronic disease <sup>c</sup>	–2.3 (–4.8 to 0.3)	.07
Chronic obstructive pulmonary disease	–2.1 (–4.3 to 0.1)	.06
Coronary heart disease	NR	NR
Stroke	0 (–5.6 to 5.8)	.99
Diabetes	0 (–2.6 to 2.7)	.99
Cancer associated with smoking <sup>d</sup>	–3.5 (–8.6 to 1.9)	.17
≥2 chronic diseases	–0.9 (–6.5 to 4.9)	.71
<b>Aged 45–64 y</b>		
Any chronic disease <sup>c</sup>	–0.8 (–1.9 to 0.3)	.15
Chronic obstructive pulmonary disease	1.2 (–0.7 to 3.2)	.17
Coronary heart disease	–0.8 (–2.2 to 0.7)	.28
Stroke	–1.1 (–3.1 to 1.0)	.27
Diabetes	–1.8 (–3.4 to –0.1)	.04
Cancer associated with smoking <sup>d</sup>	–0.8 (–3.4 to 1.9)	.51
≥2 chronic diseases	0.3 (–1.5 to 2.1)	.75
<b>Aged ≥65 y</b>		
Any chronic disease <sup>c</sup>	0.7 (–0.7 to 2.2)	.28
Chronic obstructive pulmonary disease	–0.2 (–2.0 to 1.5)	.76
Coronary heart disease		
2010–2016	5.3 (0.3 to 10.5)	.04
2016–2019	–8.6 (–20.2 to 4.7)	.15
Stroke	–0.3 (–4.6 to 4.3)	.89
Diabetes	–0.8 (–3.5 to 2.1)	.54
Cancer associated with smoking <sup>d</sup>	3.8 (–1.6 to 9.6)	.15
≥2 Chronic diseases		
2010–2016	3.8 (–1.8 to 9.8)	.15
2016–2019	–9.6 (–21.9 to 4.7)	.07

Abbreviation: NR, not reported.

<sup>a</sup> Current, daily, or some days cigarette smoking at the time of survey.

<sup>b</sup> Comparison with 2019 must be interpreted with caution because of changes to nonresponse survey weighting methodology and a questionnaire redesign in 2019.

<sup>c</sup> Any chronic disease includes people with any of the following chronic diseases associated with smoking: chronic obstructive pulmonary disease, coronary heart disease, stroke, diabetes, and cancer associated with smoking.

<sup>d</sup> Bladder, cervical, colorectal, esophageal, kidney, larynx/trachea, liver, lung, oropharynx, pancreas, and stomach cancers; data for kidney cancer were not accessible for 2019.

## ESSAY

# Building Noncommunicable Disease Workforce Capacity Through Field Epidemiology Training Programs: Experience From India, 2018–2021

Archana Ramalingam, MBBS, MD<sup>1</sup>; Mohankumar Raju, MBBS, MPH<sup>1</sup>;

Parasuraman Ganeshkumar, MBBS, MD<sup>1</sup>; Rajesh Yadav, MBBS, MSPH<sup>2</sup>;

Sukarma Tanwar, MBBS, MMed, MSPH<sup>2</sup>; Manikandanesan Sakthivel, MBBS, MD<sup>1</sup>;

Qaiser Mukhtar, PhD<sup>3</sup>; Prabhdeep Kaur, MBBS, DNB, MAE<sup>1</sup>

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## PEER REVIEWED

## Rationale

By 2003, India had started to shift from a high burden of communicable diseases to noncommunicable diseases (NCDs). By 2019, NCDs accounted for two-thirds of all deaths in India (1,2). However, the epidemiologic transition of growth of NCD burden was not uniform among all states. Thus, state-specific policy decisions and program strategies are required to address the growing NCD burden.

In response to rising NCD prevalence, India launched the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS) in 2010 to cover all districts in India (3). The program focused on prevention, screening, diagnosis, and management of hypertension, diabetes, cardiovascular disease, and cancer. Program implementation in the states has faced challenges because of a poorly designed monitoring system, interruptions in drug supply, unreliable access to diagnostics, and poor financial planning. A skilled public health workforce at the state and district levels is required to monitor, analyze, and interpret program data to identify key challenges and implement evidence-based strategies to address the challenges (4).

An approach that India is taking to strengthen the quality of the nation's public health systems relies on training the public health workforce through Field Epidemiology Training Programs (FETPs). FETPs, rooted in the concept of “learning by doing” under mentorship, impart key epidemiologic skills to the frontline public health workforce (epidemiologists, surveillance and program officers), providing them with the skills to conduct field investigations and take appropriate public health actions (5). As FETP trainees analyze program data, evaluate surveillance systems, and perform epidemiologic investigations, they develop critical thinking and problem-solving skills (6,7). Worldwide, in public health emergencies such as the COVID-19 pandemic and Ebola virus disease outbreaks, FETPs have helped build resilient health systems (8).

The initial focus of FETPs in India has been on investigating infectious diseases. However, with the ongoing epidemiologic transition and the growing NCD burden, India needs to build the capacity of public health professionals already working in the field to address NCDs and their risk factors at national and subnational levels. We describe India's efforts to build public health workforce competencies to respond to the threats of NCDs through the creation of an NCD-specific track in their FETPs.

## Establishing the NCD Track of FETP in India

The Indian Council of Medical Research's National Institute of Epidemiology, Chennai (ICMR-NIE) has nearly 2 decades of experience in conducting full-time master's-level programs built on the FETP core competencies. In 2012, a 2-year advanced FETP, the India Epidemic Intelligence Service (India EIS) program, was started at National Centres for Disease Control in India in collaboration with US Centers for Disease Control and Prevention (US-



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CDC). The goal is to have 1 trained field epidemiologist in every district (~770 districts), by selecting one among the surveillance officers, program managers, and epidemiologists in the district. In 2016, to meet the country's epidemiologists' training needs, the Ministry of Health and Family Welfare of the Government of India expanded the network of institutions offering the India EIS; ICMR-NIE was selected as one of the hubs for the program. Understanding the need for NCD-specific training, ICMR-NIE, in collaboration with CDC-India, launched a separate track of FETP for NCDs called FETP-NCD. The FETP-NCD track had 2 tiers; the FETP-NCD advanced (2-year) started in 2018 and FETP-NCD intermediate (1-year) started in 2021. The 2 tiers were started keeping in view the differing training needs of public health professionals who work in leadership positions and those working as midlevel managers.

### Collaborator consultations

Before the program's launch, the course coordinators held discussions with key collaborators to understand training needs and best practices. The participants of the meetings included officials from state public health departments (India), FETP course coordinators from other countries (Thailand, Ethiopia, China), public health experts from US-CDC and CDC-India, and FETP alumni and mentors. Inputs from these meetings contributed to the basic structure of the advanced FETP-NCD program, mentorship requirements, and recruitment strategy. The inputs also highlighted the need to add an intermediate tier targeting the competency needs of mid-level managers.

### Recruitment of trainees

The advanced FETP-NCD program admitted medical professionals who worked in leadership positions at the national, state, or district levels of the NCD program or agencies supporting NCD programs. The intermediate program admitted program managers who worked with the NCD program (medical degree not required). The candidates interested in the program applied when the admissions were open. The candidates who satisfied the eligibility criteria were interviewed. The final selection was based on a score that accounted for their additional educational qualifications, public health experience, and performance in an interview. The advanced FETP-NCD admits a maximum of 15 candidates each year and the intermediate tier admits 25 candidates.

### Basic structure of the FETP-NCD programs

The FETP-NCD programs of the ICMR-NIE are part-time in-service training (compared with full-time regular India EIS). Participants work in their respective state or district NCD placement

sites without being assigned to ICMR-NIE. The basic structure and core activities of learning (competencies) of the FETP-NCD curricula (Table) align with FETPs around the globe.

### Building a pool of dedicated mentors

Because mentoring is critical to the success of FETP-NCD, faculty mentors (1:3 mentor:mentee ratio for advanced and 1:5 for intermediate) were chosen based on their experience in field epidemiology, mentoring expertise, and interpersonal skills. FETP-NCD mentors have included scientists from NIE who work in NCDs, previous FETP graduates, and public health experts from CDC-India, multinational nongovernment organizations, and CDC-India implementing the partner South Asia Field Epidemiology and Technology Network (SAFETYNET). In addition, FETP-NCD faculty regularly participated in mentorship training and developed advancements in teaching and learning techniques and interpersonal skills. Senior mentors (those with 5 or more years of mentorship experience) support junior mentors as co-mentors.

### Progress of the advanced FETP-NCD

We initiated FETP-NCD advanced in 2018 with 5 trainees. Two of the 5 trainees graduated in 2020; the other 3 did not complete the program because of competing work commitments related to the COVID-19 response. The second cohort began in November 2019 with 8 trainees. Because of the pandemic, classroom contact sessions were hybrid, and we provided an extension to the second cohort (expected graduation in December 2022). The third cohort of 15 trainees was inducted into the advanced FETP-NCD in September 2021 and are due to graduate in September 2023.

In the initial year, program staff adapted FETP training materials to focus on NCD-related topics, including NCD-based case studies. The curriculum had a separate module on NCDs focusing on epidemiology of cardiovascular diseases, diabetes, and cancers; NCD risk factor surveillance; NCD program data analysis; and preventive strategies for NCDs.

All projects for completing the core activities of learning (Table) were done in priority areas of the NCD program in India. A few examples include 1) analysis of secondary data from the NCD program to assess the treatment outcomes (blood pressure control status) of hypertension patients, 2) field investigation to assess the reasons for missed visits by hypertension patients, 3) evaluation of the diabetes program in Kerala to understand the gaps in program implementation, and 4) an advanced epidemiology study to assess the compliance to hypertension treatment protocol by treating physicians. Each of the above-mentioned projects done as part of

the core activities of learning were vital in providing information for action to improve implementation of the national NCD program.

Cardiovascular diseases are the leading causes of deaths in India. One of the key targets of India's national NCD program is to reduce the premature mortality attributable to cardiovascular diseases by 25% by 2025, in line with the global voluntary NCD targets. Since hypertension control is critical to preventing adverse cardiovascular events, most of the trainees' projects were focused on hypertension. Two of the first cohort graduates received small, competitive grants from TEPHINET (Training Programs in Epidemiology and Public Health Interventions Network), a global network of FETPs. Since clinical inertia is one of the key factors that affect blood pressure control in the population, one of the small grant projects focused on assessing the compliance of physicians in primary and secondary care health centers to hypertension treatment protocols. The study found that nearly three-fifths of the prescriptions by physicians adhered to treatment protocol. After the study concluded, refresher trainings were done for the physicians, emphasizing the need to adhere to the treatment protocol. The second small grant project focused on forecasting, procurement process, and availability of protocol-based antihypertensive drugs at public health facilities in 4 states (Punjab, Madhya Pradesh, Telangana, and Maharashtra) of India between June 2019 and May 2020. The study found that the drug forecasting tool (provided as part of the India Hypertension Control Initiative) helped improve drug availability over time. It also found a gap in the knowledge of district level NCD nodal officers about the drug forecasting process, which was later addressed through refresher trainings. These examples demonstrate that the FETP trainees' projects generate vital information that is used for planning interventions to improve the NCD program. In addition, during COVID-19, the FETP-NCD trainees also led innovations to ensure continuum of care for hypertension patients, including establishing door-to-door drug delivery systems and designing and implementing telehealth services (9,10). The FETP trainees also routinely disseminate findings from the projects to the state ministries of health for necessary public health action. They also presented some of the projects at conferences to share the best practices, sometimes winning the best paper presentations.

### **Progress of the intermediate FETP-NCD**

We initiated the intermediate FETP-NCD at ICMR-NIE in October 2021. The first cohort of the intermediate FETP-NCD started with 22 trainees from 10 different states in India. The trainees conducted NCD program data analysis (screening, diagnosis, and treatment) at the district and state levels, providing critical information on hypertension or diabetes control rates.

## **Challenges**

Despite rapid expansion, high demand, and early success, both FETP-NCD programs have numerous challenges. Lack of buy-in from state health departments because of lack of prioritization of NCDs remains a challenge. The trained FETP alumni are often underused (assigned additional clinical responsibilities rather than public health-related duties). The absence of defined career pathways following program completion deters candidates from applying. Given the in-service training model, difficulties balancing work-related commitments while fulfilling rigorous training requirements lead to dropouts. Identifying, developing, and retaining mentors for the FETP-NCD is another major challenge. Finally, innovative solutions are required to reduce the administrative burden of program expansion.

## **Way Forward**

ICMR-NIE is initiating state-specific intermediate FETP-NCD with the state health leadership in Chhattisgarh and Odisha to train 1 person in NCDs in every district. In this state-specific model, ICMR-NIE plans to enroll state-nominated trainees in each state and conduct in-person training sessions and mentorship in the respective states with support from full-time state-based mentors. The intermediate FETP-NCD, tailored to state-specific needs, allows the state health department to take ownership of the program and identify the training needs and priorities for field projects. Efforts are under way to mitigate workload by aligning the core activities of learning with the on-the-job profile of the trainees and increasing acceptability by preparing for TEPHINET accreditation of the FETP-NCD. In addition, India needs to establish networks for FETP alumni and faculty for experience sharing, mutual learning, and increasing the available pool of mentors. Beyond this, to ensure sustainability and scale-up, policy makers at the state and central ministries of health need to allocate sufficient funds for mentor trainings. Finally, digital innovations such as learning management software currently being piloted in India will improve the delivery of FETPs and reduce administrative burden.

In light of India's large population and 770 districts, commitment from leadership, funding, and ownership from the Ministry of Health and Family Welfare and states will be required to scale and sustain advanced and intermediate FETP-NCD. Advanced FETP-NCD is needed to develop skilled public health leaders at the national, regional, and state levels. Intermediate FETP-NCD is expandable, can be embedded in the state health systems, and is more suited for the competency needs of the state and district-level public health workforce. FETP-NCD programs will better equip India with a skilled workforce to address the increasing NCD burden and serve as a model for other FETPs.

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## Author Information

Corresponding Author: Prabhdeep Kaur, MBBS, DNB, MAE, National Institute of Epidemiology (ICMR) — Noncommunicable Diseases, R-127 3rd Ave, TNHB Chennai, Tamil Nadu 600077 India. Telephone: +914426136233. Email: kprabhdeep@gmail.com.

Author Affiliations: <sup>1</sup>National Institute of Epidemiology, Indian Council of Medical Research, Chennai, Tamil Nadu, India. <sup>2</sup>Centers for Disease Control and Prevention, New Delhi, Delhi, India. <sup>3</sup>Centers for Disease Control and Prevention, Atlanta, Georgia, USA.

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Table

Table. Structure of the Advanced and Intermediate Field Epidemiology Training Programs (FETPs) for Noncommunicable Diseases (NCDs), India

Domain	Advanced FETP	Intermediate FETP
<b>Targeted learners</b>	National and state level NCD nodal officers (physicians)	District NCD nodal officers and program managers (physicians and allied public health professionals)
<b>Duration</b>	2 years: <ul style="list-style-type: none"> <li>Classroom training (12–14 weeks)</li> <li>Field posting (72–74 weeks)</li> </ul>	1 year: <ul style="list-style-type: none"> <li>Classroom training (8–10 weeks)</li> <li>Field posting (38–40 weeks)</li> </ul>
<b>Mode of training</b>	<ul style="list-style-type: none"> <li>In-person workshop sessions</li> <li>Webinars</li> <li>Small group training at field posting sites</li> </ul>	<ul style="list-style-type: none"> <li>In-person workshop sessions</li> <li>Webinars</li> <li>Small group training at field posting sites</li> </ul>
<b>Teaching–learning methods</b>	<ul style="list-style-type: none"> <li>Lectures</li> <li>Group discussion</li> <li>Case studies</li> <li>Hands-on training (Microsoft Corporation applications, Epi Info version 7.2)</li> <li>Fieldwork</li> </ul>	<ul style="list-style-type: none"> <li>Lectures</li> <li>Group discussion</li> <li>Case studies</li> <li>Hands-on training (Microsoft Corporation applications, Epi Info version 7.2)</li> <li>Fieldwork</li> </ul>
<b>Mentor: mentee ratio</b>	<ul style="list-style-type: none"> <li>1:3</li> </ul>	<ul style="list-style-type: none"> <li>1:5</li> </ul>
<b>Core activities of learning (no. required for graduation)</b>	<ul style="list-style-type: none"> <li>Secondary data analysis of program data (2)</li> <li>Field investigation (1)</li> <li>Planned analytical epidemiology study (1)</li> <li>Program evaluation (1)</li> <li>Abstract (1)</li> <li>Manuscript (1)</li> <li>Oral or poster presentation at a scientific conference (1)</li> </ul>	<ul style="list-style-type: none"> <li>Secondary data analysis of program data (1)</li> <li>Field investigation (1)</li> <li>Group work: analytical epidemiology study (1)</li> <li>Group work: program evaluation (1)</li> <li>Abstract (1)</li> <li>Oral or poster presentation at a scientific conference (1)</li> </ul>

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## ORIGINAL RESEARCH

# Disparities in Influenza Vaccination Coverage and Associated Factors Among Adults with Cardiovascular Disease, United States, 2011–2020

Tarang Parekh, PhD, MBBS<sup>1,2</sup>; Zulqarnain Javed, PhD, MBBS, MPH<sup>2</sup>; Safi U. Khan, MD<sup>3</sup>;  
Hong Xue, PhD<sup>1</sup>; Khurram Nasir, MD, MPH, MSc<sup>2,3</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

Influenza vaccination has been shown to reduce cardiovascular illness and death, and routine annual influenza vaccination is recommended by the Centers for Disease Control and Prevention.

**What is added by this report?**

We found marginal improvement in influenza vaccination during the past decade among adults with cardiovascular disease, lagging far behind the Healthy People 2020 goal. Vaccination prevalence is influenced by social determinants of health such as race and ethnicity, access to preventive services, and geographic location.

**What are the implications for public health practice?**

We can achieve Healthy People 2030 goals for vaccine-preventable disease only if we prioritize socially vulnerable populations and look beyond clinical settings as a place of vaccination.

## Abstract

**Introduction**

Influenza vaccination can reduce the incidence of cardiovascular disease (CVD) in the US. However, differences in state-level trends in CVD and sociodemographic and health care characteristics of adults with CVD have not yet been studied.

**Methods**

In this repeated cross-sectional study, we extracted 476,227 records of adults with a self-reported history of CVD from the Behavioral Risk Factor Surveillance System from January 2011 through December 2020. We calculated the prevalence and likelihood of annual influenza vaccination by sociodemographic characteristics, health care characteristics, and CVD risk factors. Additionally, we examined annual trends of influenza vaccination by geographic location.

**Results**

The annual age-adjusted influenza vaccination rate among adults with CVD increased from 38.6% (2011) to 44.3% (2020), with an annual average percentage change of 1.1%. Adults who were aged 18 to 44 years, male, non-Hispanic Black/African American, or Hispanic, or had less than a high school diploma, annual household income less than \$50,000, and no health insurance had a lower prevalence of vaccination. The odds of vaccination were lower among non-Hispanic Black/African American (adjusted odds ratio, 0.73; 95% CI, 0.70–0.77) and non-Hispanic American Indian/Alaska Native (adjusted odds ratio, 0.86; 95% CI, 0.75–0.98) compared with non-Hispanic White adults. Only 16 states achieved a vaccination rate of 50%; no state achieved the Healthy People 2020 goal of 70%. Nonmedical settings (supermarkets, drug stores) gained popularity (19.2% in 2011 to 28.5% in 2018) as a vaccination setting.

**Conclusion**

Influenza vaccination among adults with CVD improved marginally during the past decade but is far behind the targeted national goals. Addressing existing disparities requires attention to the role of social determinants of health in determining access to vaccination, particularly among young people, racial and ethnic minority populations, people who lack health insurance, and people with comorbidities.



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## Introduction

During the past 2 decades, annual influenza vaccination has been a cornerstone of national efforts such as Healthy People to achieve a target vaccination rate of 70% and protect against influenza (1). The American Heart Association and the American College of Cardiology recommend influenza vaccination for secondary prophylaxis of cardiovascular diseases (CVD), reflecting growing evidence of the protective role of vaccination (Class I, Level of Evidence B) (1,2). A recent study reported an increased risk of acute myocardial infarction (AMI) within 7 days of contracting infection with influenza A and influenza B virus (3). Several mechanisms have been proposed to explain the increased risk of CVD, including immune complex deposition in atherosclerotic plaques and subsequent thrombosis and elevated macrophage circulation in arteries (4,5). Current evidence suggests that such adverse outcomes may be prevented with influenza vaccination (3,6,7).

The efficacy of influenza vaccination in preventing AMI has been estimated at 15% to 45%, which is comparable to the documented efficacy of traditional CVD prevention measures such as smoking cessation (32%–43%), statins (19%–30%), and antihypertensive therapy (17%–25%) (6). However, there is a paucity of data on influenza vaccination rates and related sociodemographic differences among adults with CVD. Furthermore, little is known about potential state-level differences in vaccination coverage. To address this gap, we sought to evaluate the national and regional trends of influenza vaccination among adults with CVD. We also examined patterns and predictors of annual influenza vaccination among adults with CVD by key sociodemographic and health care characteristics considered to be social determinants of health.

## Methods

### Data source and study design

We abstracted data from the Behavioral Risk Factor Surveillance System (BRFSS), a nationwide annual telephonic health survey of noninstitutionalized adults aged 18 years or older living in the 50 US states, the District of Columbia, and US territories on health-related risk behaviors, chronic health conditions, and use of preventive services (8). BRFSS is a collaborative project between US states and territories and the Centers for Disease Control and Prevention (CDC). State health departments manage BRFSS field operations with technical assistance from CDC. The structured survey questionnaire is designed and approved by a working group of BRFSS state coordinators and CDC staff members before the beginning of each calendar year. BRFSS conducts surveys via landlines and cellular telephones by using trained survey administrators and random-digit-dialing methods to identify respondents and

computer-assisted telephone interview systems to perform structured scripted interviews. For landline telephone sampling, BRFSS divides telephone numbers into 2 strata, high density and medium density, which are determined by the number of listed household numbers in a set of 100 telephone numbers with the same area code, prefix, and first 2 digits of the suffix and all possible combinations of the last 2 digits. For cellular telephone sampling, a commercially available frame is used, whereby the system can call random samples of cellular telephone numbers. The study was determined to be exempt from review by the institutional review board at George Mason University.

We included in our analysis adults aged 18 years or older surveyed from January 2011 through December 2020 with a history of heart attack/myocardial infarction, angina/coronary heart disease (CHD), or stroke. Approximately 6.4% of respondents with CVD were missing information on influenza vaccination and were excluded from our analytic sample. The final sample comprised 476,227 adults with CVD and accounted for 8.5% of the BRFSS survey sample conducted from 2011 through 2020. Median survey responses ranged from 45.1% to 49.9% for the study period.

### Study variables

Annual influenza vaccination was defined as receipt of an influenza vaccination within 12 months before the interview date. Sociodemographic covariates include age (categorized as 18–44, 45–64 years, and  $\geq 65$  years), sex (male, female), race and ethnicity (Hispanic, non-Hispanic American Indian/Alaska Native, non-Hispanic Asian, non-Hispanic Black/African American, non-Hispanic Hawaiian/Pacific Islander, non-Hispanic White, and non-Hispanic other), education level (some high school or less, high school graduate, some college or technical school, college graduate), annual household income ( $< \$50,000$  or  $\geq \$50,000$ ), marital status (married; unmarried; divorced, widowed, or separated), and US Census–defined geographic region (New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific, US Islands). Health care characteristics were having any health insurance (yes/no), having a personal doctor or health care provider (hereinafter, personal health care provider) (yes/no), and time since the most recent visit to the personal health care provider for a routine checkup. Primary risk factors for CVD included diabetes, obesity (body mass index  $> 30.0$ ), and smoking status (never, former, and current).

### Statistical analysis

The survey procedures (svyset) in Stata version 17.0 (StataCorp LLC) were used to account for the complex sampling design and BRFSS survey weights and to determine national and state-level

population estimates. To compute direct age-adjusted estimates, we used 2010 US Census population proportions for groups aged 18 to 44 years, 45 to 64 years, and 65 years or older. We first performed a descriptive analysis of sociodemographic characteristics, health care characteristics, and CVD risk factors, and we used a  $\chi^2$  test to compare the distribution of these characteristics among participants with and without a history of CVD.

For our primary analysis, we examined the age-adjusted frequency distribution (% prevalence and 95% CI) of annual influenza vaccination coverage among adults with CVD each year from 2011 through 2020. We used Joinpoint trend analysis software version 4.9.1.0 (National Cancer Institute) (9) to analyze temporal trends in age-adjusted prevalence of influenza vaccination by years across all characteristics. The Joinpoint regression fits trend data from start to end years and identifies trend segments with significant changes in trend. For each trend segment in the selected model, the annual percentage change (APC) is calculated to characterize trends over time per segment. The average APC (AAPC) for all years (2011–2020) was obtained as a weighted APC. In our trend analysis, with 10 years of data points, the modeling was restricted to a maximum of 2 joinpoints. Modeling selection was based on the permutation test and evaluated if a change occurred in any segment; a *P* value of <.05 was considered significant.

In a secondary analysis, we examined various places for vaccination among participants who reported receiving the vaccine in the past 12 months. BRFSS has the following response options: doctor's office or health maintenance organization (HMO); health department; another type of clinic or health center (a community health center); senior, recreation, or community center; store (supermarket, drug store); hospital (inpatient); emergency room; workplace; some other kind of place; school; received vaccination in Canada/Mexico; don't know/not sure; and refused. We combined categories into the following: doctor's office (including HMO), other health care facility (health department, another type of clinic or health center, and community health center), hospital/emergency room, store, workplace, and other (senior or recreation center, some other kind of place, school, outside US, and don't know/not sure/refused). This analysis was performed by using the core questionnaire module for the years 2011, 2012, 2015, and 2018. Because of limited years of data for place of vaccination, we did not perform trend analysis and reported only age-adjusted prevalence.

Multivariate logistic regression models were weighted to estimate the adjusted odds ratios (AOR) and 95% CIs of influenza vaccination associated with each sociodemographic characteristic, health care characteristic, and CVD risk factor. Furthermore, to account

for possible state-level differences and temporal trends in vaccination rates, we generated year and state fixed-effects logistic regression models. A 2-sided *P* value of .05 was used to determine significance.

## Results

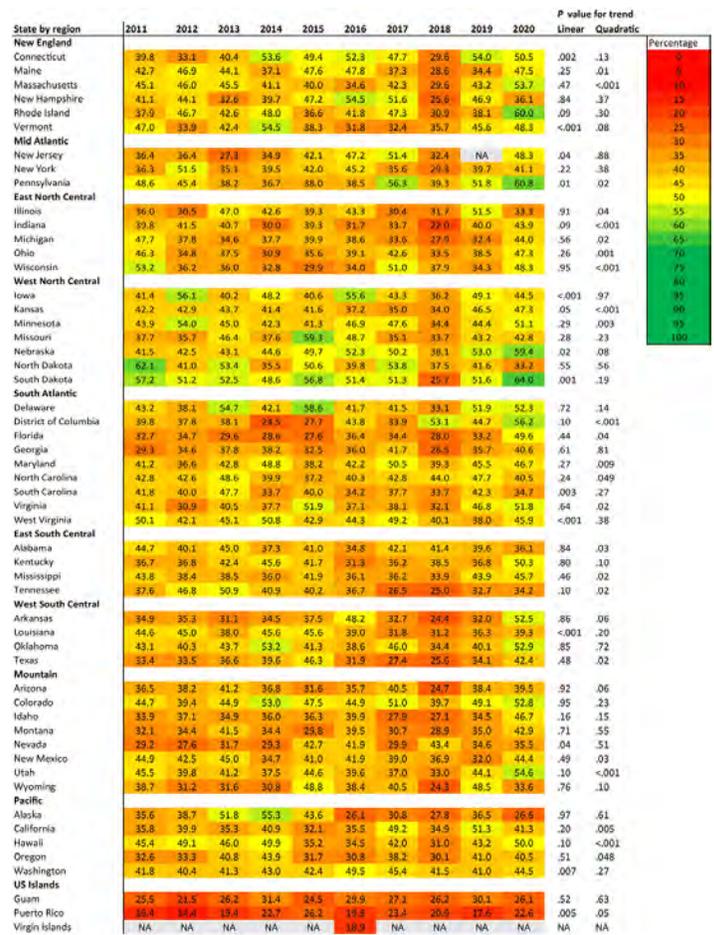
Adults with CVD were more likely than adults without CVD to be aged 65 years or older (51.2% vs 16.9%), male (55.4% vs 47.8%), non-Hispanic White (71.5% vs 64.3%), and a high school graduate or less (52.0% vs 40.3%), and have an annual household income of less than \$50,000 (69.4% vs 50.4%) (Supplemental Table 1 in Appendix). The prevalence of diabetes (31.7% vs 9.7%), obesity (38.0% vs 28.8%), and current smoking (20.4% vs 16.5%) was greater among adults with CVD than among adults without CVD. Most adults with CVD had health insurance (91.8%), had a personal health care provider (91.0%), and had a visit with the personal health care provider within the past year (85.8%); the prevalence of each of these characteristics was higher among adults with CVD than among adults without CVD (85.7%, 76.6%, and 69.7%, respectively). The influenza vaccination rate was consistently higher among adults with CVD than among adults without CVD (Supplemental Figure in Appendix); however, the gap in prevalence decreased from 2011 through 2020.

Among adults with CVD, the age-adjusted prevalence of influenza vaccination increased from 38.6% in 2011 to 44.3% in 2020 (Supplemental Table 2 in Appendix) with an average APC of 1.1% (Table 1). The APC in influenza vaccination changed from a 4.5% decrease per year during 2015 through 2018 to a 14.1% increase per year during 2018 through 2020. By type of CVD, vaccination rates were highest among adults with a history of angina/CHD (46.9%) and lowest among adults with a history of myocardial infarction (40.1%) in 2020. Influenza vaccination rates were consistently lower among adults aged 18 to 44 years (vs adults aged 45–64 and  $\geq 65$  years) and men (vs women). Among racial and ethnic minority groups in 2020, Asian adults had the highest vaccination rate (50.4%), while American Indian/Alaska Native (40.3%), non-Hispanic Black/African American (43.3%), and Hispanic (36.8%) adults had lower rates.

Although the AAPC in influenza vaccination prevalence among adults aged 45 to 64 years with CVD was a nonsignificant 1.4%, the prevalence increased significantly during 2018 through 2020 (APC, 12.6%) (Table 1). The overall prevalence of influenza vaccination increased among both men and women, with a greater increase during the last trend segment (2018–2020). The AAPC was 2.9% among college graduates, with prevalence ranging from 46.2% in 2011 to 59.1% in 2020. Although the prevalence of influenza vaccination was higher among adults with diabetes than

among adults without diabetes, the prevalence increased significantly among adults without diabetes during 2011 through 2020 (AAPC, 1.9%). Among never and former smokers, influenza vaccination increased at a significant AAPC of 1.9%, with a greater increase during 2018 through 2020 among never smokers (APC, 14.1%) and former smokers (APC, 15.1%). Adults with a personal health care provider had consistently higher vaccination rates than adults without one (42.1% vs 23.5% in 2011; 47.9% vs 26.1% in 2020); the AAPC was 1.8% for both groups, and the largest increase for both groups was during 2018 through 2020 (has a personal health care provider, 13.2%; does not have a personal health care provider, 19.2%). The AAPC in the prevalence of influenza vaccination was 1.7% (42.7% in 2011 to 48.8% in 2020) among adults with a visit to a personal health care provider within the past 1 year, -0.1% (30.7% in 2011 to 29.4% in 2020) among adults reporting 1 or 2 years since their most recent visit, and -2.3% (25.8% in 2011 to 20.1% in 2020) among adults reporting more than 2 years since their most recent visit.

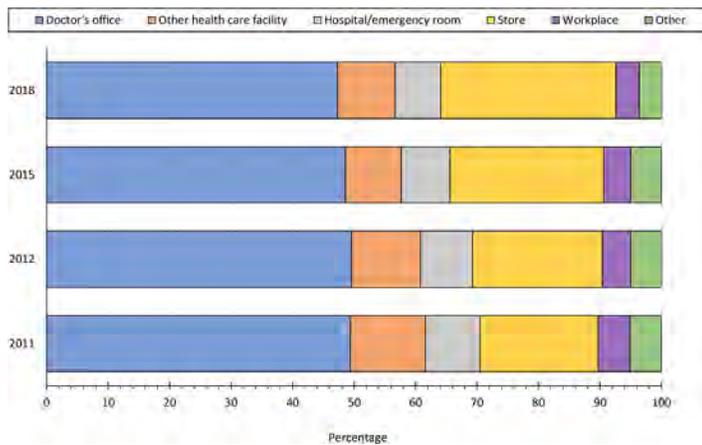
In 2020, the age-adjusted influenza vaccination rate among adults with CVD ranged from 22.6% in Puerto Rico to 64.0% in South Dakota (Figure 1). From 2011 to 2020, the vaccination rate showed a significant positive linear trend in 9 states (Connecticut, Iowa, Nebraska, Nevada, New Jersey, Pennsylvania, South Dakota, Vermont, Washington) and Puerto Rico. A negative linear trend was observed in 3 states (Louisiana, South Carolina, West Virginia). Overall, West North Central region states performed well in influenza vaccination rates during the study period. Only 16 states achieved a vaccination rate of 50%, and no state achieved the Healthy People 2020 goal of 70%.



**Figure 1.** State-specific trends in the prevalence of influenza vaccination among US adults with cardiovascular disease, Behavioral Risk Factor Surveillance System, 2011–2020. Linear and quadratic trends were calculated by using adjusted regression models with survey years modeled as orthogonal polynomials. Abbreviation: NA, not available.

Doctors' offices remained the most common place for annual influenza vaccination among US adults with CVD, despite consistently declining vaccination rates from 2011 (49.4%) to 2018 (47.3%); we observed similar declines for other health care facilities. In contrast, the preference for stores such as supermarkets or drug stores as vaccination sites steadily increased from 19.2% in 2011 to 28.5% in 2018 (Figure 2).

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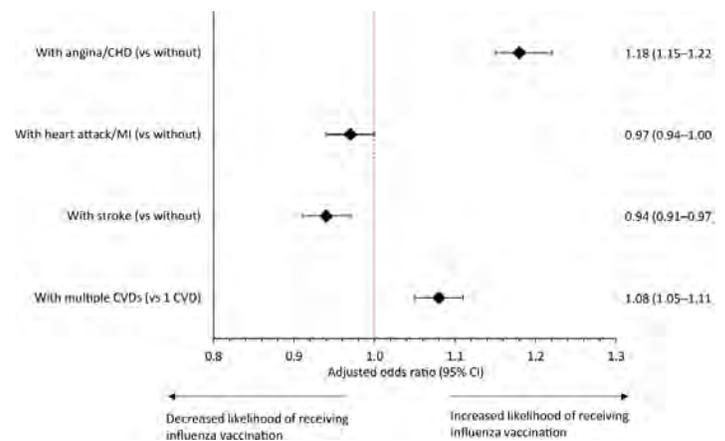


**Figure 2.** Common places for receiving an annual influenza vaccination among US adults with cardiovascular disease, Behavioral Risk Factor Surveillance System, 2011–2020. “Other health care facility” includes health department, another type of clinic or health center, and a community health center. Store includes supermarkets or drug stores. “Other place” includes senior or recreation center, some other kind of place, school, received outside US, and don’t know/not sure/refused.

Compared with adults with CVD aged 18 to 44 years, adults aged 45 to 64 years (AOR, 1.50; 95% CI, 1.41–1.61) and adults aged 65 years or older (AOR, 2.58; 95% CI, 2.40–2.76) had greater odds of getting an influenza vaccination (Table 2). Women had marginally higher odds (AOR, 1.06; 95% CI, 1.03–1.10) of getting the influenza vaccination than men. Compared with non-Hispanic White adults with CVD, Hispanic adults with CVD had 23% lower odds of getting the annual influenza vaccination (AOR, 0.77; 95% CI, 0.72–0.82) with year-fixed effects, which was not significant when state effects were added. Odds of getting an influenza vaccination were 27% and 14% lower, respectively, among non-Hispanic Black/African American adults (AOR, 0.73; 95% CI, 0.70–0.77) and American Indian/Alaska Native (AOR, 0.86; 95% CI, 0.75–0.98) adults with CVD compared with non-Hispanic White adults with CVD. The odds of getting an influenza vaccination increased consistently as level of education increased. Adults with CVD and diabetes were 29% more likely to get an influenza vaccination (AOR, 1.29; 95% CI, 1.25–1.33) than adults with CVD and no diabetes. Compared with nonsmoking adults with CVD, former smokers with CVD were 15% more likely to get an influenza vaccination (AOR, 1.15; 95% CI, 1.11–1.19). In contrast, current smokers with CVD were 21% less likely to get an annual influenza vaccination (AOR, 0.79; 95% CI, 0.76–0.83) than nonsmoking adults with CVD. Having health insurance (AOR, 1.76; 95% CI, 1.63–1.89) and a personal health care provider (AOR, 1.71; 95% CI, 1.60–1.83) increased the likelihood of influ-

enza vaccination. The odds of getting an annual influenza vaccination decreased as time increased since the most recent visit to a personal health care provider for a routine checkup.

The likelihood of receiving an annual influenza vaccination differed by type of CVD. The odds of receiving an annual influenza vaccination were significantly greater among adults with a history of angina/CHD (AOR, 1.18; 95% CI, 1.15–1.22;  $P < .001$ ) than among adults without a history of angina/CHD. In contrast, odds were marginally lower among adults with a history of stroke (AOR, 0.94; 95% CI, 0.91–0.97;  $P < .001$ ) compared with adults with no history of stroke (Figure 3).



**Figure 3.** Results of multivariate regression models showing association between annual influenza vaccination and types of cardiovascular disease among US adults, Behavioral Risk Factor Surveillance System, January 2011–December 2020. Models were adjusted for reported sociodemographic characteristics, health care characteristics, and cardiovascular disease risk factors. Error bars indicate 95% CIs. Except for heart attack/myocardial infarction, odds are significant at  $P < .05$  by 2-sided z test. Abbreviations: CHD, coronary heart disease; CVD, cardiovascular disease; MI, myocardial infarction.

## Discussion

This study found a slight improvement in influenza vaccination coverage among adults with CVD during the past decade; however, vaccination rates remained consistently below national goals (1). We found that young adults had lower vaccination rates than middle-aged and older adults, and rates among young adults did not improve during the study period. This lack of improvement may be attributed to a lower perceived risk of influenza in this population (10). The prevalence of influenza vaccination was consistently lower among middle-aged adults, supporting findings from a previous study that reported lower rates among this age group compared with adults aged 65 years or older (11). By race and ethnicity, only non-Hispanic White adults showed improvements in influenza vaccination rates. Furthermore, we found that

non-Hispanic Black/African American and American Indian/Alaska Native adults were consistently less likely than non-Hispanic White adults to get annual influenza vaccinations, which may reflect persistent racial disparities in the use of preventive services and mistrust of clinical research activities (12,13). Our findings may also be attributed to various social determinants of health, including access to preventive care and treatment; such missed opportunities for preventive care and treatment among racial and ethnic minority populations merit further study (10,14).

Adults with CVD and without health insurance, without a personal health care provider, and without a recent visit to a personal health care provider for a routine checkup had lower vaccination rates than adults with health insurance, a personal health care provider, and a visit. The influence of such modifiable social determinants of health on vaccination rates highlights the underlying structural barriers, such as access to routine care, to adherence to preventive health guidelines (14). Moreover, the popularity of nonmedical settings such as workplaces, supermarkets, and drug stores as vaccination sites provides an opportunity to extend vaccination efforts beyond traditional medical settings to achieve the Healthy People 2030 target for influenza vaccination.

In this study, among adults with CVD, we found a consistently lower prevalence of influenza vaccination among current smokers than among never and former smokers. Current smoking was also identified in regression analyses as significantly lowering the odds of influenza vaccination. In contrast, among adults with CVD, former smokers (compared with never smokers) and adults with diabetes (compared with adults without diabetes) had a greater likelihood of influenza vaccination, consistent with previous literature on the general population (15,16). Smoking has contributed to nearly 25% of hospitalizations attributable to influenza, which could be prevented with vaccination (17).

In 2020, 44.3% of adults with CVD received an influenza vaccination in the US, and more than half of states are above this national average, which was the highest in any year during the study period. This relatively high prevalence was likely due to the surge in influenza vaccination uptake as protection against COVID-19 (18). During the past decade, influenza vaccination rates among adults with CVD varied significantly by state, and all states fell below the national target of 70%. Rates were comparatively higher in New England and the West North Central region and lower in the East South Central and Pacific regions. State-level differences may have been driven by preexisting social determinants of health such as economic burden, lack of transportation, lower rate of insurance coverage, vaccination mandates for certain populations, and allowed exemptions (15,19–23). Also, the discrepancy between state vaccination rates and the national goal underscores the need to further analyze data to understand the needs of states

according to the unique demographic characteristics of each state. Future efforts should focus on identifying both personal and system-level barriers to uptake of influenza vaccination, including issues related to individual perceptions, resource allocation, and the infrastructure for delivering preventive care (22,24).

Our findings have important implications for state and national COVID-19 vaccination goals. The current administration has taken an active role in administering and distributing COVID-19 vaccinations. However, rollout responsibilities have still largely been borne by states, and our findings demonstrate that much work must be done to address the issue of vaccination acceptance among diverse population groups, especially among racial and ethnic minority populations, people with low socioeconomic status, people who lack health insurance, and people with comorbidities.

### Strengths and limitations

The primary strength of our study is that, to our knowledge, it is the largest and most current survey to report the national prevalence of influenza vaccination with validated survey questions on vaccination receipt (25). Moreover, the BRFSS methodology has been used and evaluated by CDC and participating states for more than 4 decades (8). In addition, our study is the first to report age-adjusted trends, by state, among adults with CVD with various sociodemographic and health care characteristics. Nonetheless, the strength of association in our findings should be interpreted with caution. The large study sample size may render weak associations significant. Furthermore, the cross-sectional design of the survey precludes causal inferences. In addition, the telephonic survey data are self-reported, so recall bias and some misclassification cannot be ruled out. However, previous studies showed that self-reported BRFSS data on influenza vaccination status and chronic conditions had better validity than self-reported data from other surveys (26–28). Although BRFSS has been conducted in all 50 states, New Jersey was not included in the 2019 survey year; furthermore, among US territories, only Guam and Puerto Rico collected data for all years, and the Virgin Islands collected data for the 2016 survey year only. We noted an approximate 6% decrease from 2017 to 2018 and then an 8 percentage-point increase in influenza coverage in 2019, similar to findings from a CDC report on vaccination coverage (29). Although the reason for the decrease in 2018 is not clear, the estimates in 2019 were consistent with other national surveillance data on influenza vaccination as reported by CDC (29,30). Also, we were not able to evaluate reasons for state-specific differences in influenza vaccination prevalence, and the reasons for opting in or opting out of vaccination. Although the COVID-19 pandemic caused disruptions in data collection for many national surveys, BRFSS was unlikely to be affected because of its use of state-of-the-art telephonic data collection methods; the response rate was 47.9% in 2020.

## Conclusion

These findings highlight significant disparities in influenza vaccination rates among adults with CVD and underline the relevance of social determinants of health toward achieving target vaccination rates (2), particularly among young people, racial and ethnic minority populations, people with comorbidities, and people who lack health insurance and a regular source of care. Our results have implications for policies on vaccine-preventable diseases, such as COVID-19, which should prioritize socially vulnerable populations and look beyond clinical settings as a place of vaccination to achieve Healthy People 2030 goals.

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## Author Information

Corresponding Author: Tarang Parekh, PhD, MBBS, Center for Health Data Science and Analytics, Houston Methodist Hospital, 7550 Greenbriar Dr, Houston, TX 77030. Telephone: 571-224-2927. Email: [tparekh@houstonmethodist.org](mailto:tparekh@houstonmethodist.org).

Author Affiliations: <sup>1</sup>Department of Health Administration and Policy, George Mason University, Fairfax, Virginia. <sup>2</sup>Center for Health Data Science and Analytics, Houston Methodist Hospital, Houston, Texas. <sup>3</sup>Houston Methodist DeBakey Heart and Vascular Center, Houston, Texas.

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Tables

**Table 1. Age-Adjusted Prevalence of Influenza Vaccination and Annual Percentage Change by Selected Characteristics, US Adults With Cardiovascular Disease, Behavioral Risk Factor Surveillance System, January 2011–December 2020<sup>a</sup>**

Characteristic	Age-adjusted prevalence, %		Average annual percentage change (95% CI)	Annual percentage change (95% CI)		
	2011	2020	2011–2020	Trend segment 1, 2011–2015	Trend segment 2, 2015–2018	Trend segment 3, 2018–2020
<b>Cardiovascular disease</b>						
Any cardiovascular disease <sup>a</sup>	38.6	44.3	1.1 (1.1 to 2.6) <sup>b</sup>	1.0 (–0.1 to 2.1)	–4.5 (–8.0 to –0.9) <sup>b</sup>	14.1 (10.0 to 18.4) <sup>b</sup>
Angina/coronary heart disease only	39.1	46.9	2.5 (1.0 to 5.0) <sup>b</sup>	0.6 (–3.5 to 4.9)	–1.4 (–15.2 to 14.7)	10.6 (4.5 to 25.7) <sup>b</sup>
Stroke only	38.6	42.9	1.8 (–3.0 to 6.8)	1.3 (–6.2 to 9.3)	–3.9 (–25.2 to 23.6)	11.9 (–12.4 to 42.8)
Myocardial infarction only	32.8	40.1	2.3 (–6.4 to 11.7)	2.3 (–11.0 to 17.6)	–6.4 (–39.9 to 46.0)	16.7 (–28.8 to 91.1)
≥2 Cardiovascular diseases	43.5	46.6	1.4 (–4.0 to 7.0)	–0.1 (–7.6 to 8.0)	–6.9 (–30.1 to 24.0)	18.5 (–9.7 to 55.5)
<b>Age, y</b>						
18–44	27.5	33.3	2.7 (–1.6 to 7.3)	2.2 (–4.6 to 9.5)	–5.6 (–24.6 to 18.1)	17.9 (–5.2 to 46.8)
45–64	42.7	48.1	1.4 (–2.8 to 5.7)	0.4 (–5.5 to 6.6)	–4.3 (–22.7 to 18.6)	12.6 (16.5 to 41.5) <sup>b</sup>
≥65	61.4	67.5	1.2 (–1.5 to 4.0)	0.2 (–3.6 to 4.1)	–2.5 (–15.3 to 12.2)	9.6 (–5.3 to 26.7)
<b>Sex</b>						
Male	36.4	41.8	1.6 (1.1 to 2.3) <sup>b</sup>	1.3 (0.2 to 2.3) <sup>b</sup>	–5.1 (–8.3 to –1.9) <sup>b</sup>	13.6 (10.0 to 17.3) <sup>b</sup>
Female	41.1	47.2	2.0 (0.1 to 3.9) <sup>b</sup>	0.6 (–2.2 to 3.4)	–3.8 (–12.6 to 5.9)	14.3 (3.8 to 25.9) <sup>b</sup>
<b>Race and ethnicity</b>						
American Indian/Alaska Native, non-Hispanic	41.4	40.3	0.8 (–1.2 to 2.1)	–3.3 (–6.3 to 0.3)	–10.4 (–27.8 to 6.2)	20.9 (–17.6 to 58.1)
Asian, non-Hispanic	34.6	50.4	4.2 (–0.2 to 5.6)	0.9 (–0.5 to 2.3)	–10.2 (–24.1 to 3.6)	1.4 (–31.2 to 49.5)
Black/African American, non-Hispanic	36.2	43.3	3.2 (–5.3 to 12.4)	3.4 (–9.3 to 16.1)	–5.4 (–15.1 to 4.2)	17.0 (–29.6 to 94.6)
Hispanic	33.9	36.8	1.0 (–1.0 to 3.1)	1.2 (–2.1 to 4.6)	–2.5 (–12.0 to 8.0)	6.4 (–4.9 to 19.0)
Native Hawaiian/Pacific Islander, non-Hispanic	39.7	46.1	2.4 (–4.9 to 10.1)	–6.6 (–16.5 to 4.5)	–9.2 (–27.0 to 8.6)	11.5 (–20.0 to 55.4)
White, non-Hispanic	39.7	46.3	1.9 (1.2 to 2.6) <sup>b</sup>	1.1 (–0.1 to 2.2)	–6.1 (–9.6 to –2.5) <sup>b</sup>	17.1 (13.1 to 21.2) <sup>b</sup>
Other, non-Hispanic	36.7	40.4	0.9 (–1.3 to 2.1)	6.8 (–6.7 to 20.1)	–6.0 (–17.1 to 5.0)	3.3 (–24.4 to 41.1)
<b>Education</b>						
Some high school or less	32.5	36.2	0.9 (–1.3 to 3.1)	1.9 (–1.5 to 5.5)	–6.1 (–16.2 to 5.3)	9.9 (–2.0 to 23.2)
High school graduate	37.5	41.0	1.1 (–1.9 to 4.1)	–0.9 (–5.3 to 3.6)	–3.0 (–17.0 to 13.3)	11.9 (–4.3 to 30.8)
Some college or technical school	40.4	44.2	1.6 (–0.2 to 3.5)	0.8 (–1.9 to 3.5)	–4.0 (–12.8 to 5.7)	12.6 (3.1 to 23.0) <sup>b</sup>
College graduate	46.2	59.1	2.9 (1.0 to 4.9) <sup>b</sup>	2.3 (–0.9 to 5.6)	–5.4 (–14.1 to 4.3)	18.1 (6.2 to 31.3) <sup>b</sup>
<b>Annual household income, \$</b>						
<50,000	36.7	41.8	1.7 (–1.1 to 4.6)	0.6 (–3.6 to 5.0)	–4.8 (–17.6 to 10.0)	14.7 (–0.8 to 32.6)
≥50,000	44.5	49.7	1.9 (–3.5 to 7.5)	2.4 (–5.6 to 11.2)	–6.7 (–30.1 to 24.6)	14.8 (–12.3 to 50.4)
<b>Marital status</b>						
Married	39.9	50.0	2.5 (1.8 to 3.3) <sup>b</sup>	1.5 (0.4 to 2.5) <sup>b</sup>	–6.2 (–9.8 to –2.6) <sup>b</sup>	19.6 (15.3 to 24.2) <sup>b</sup>

<sup>a</sup> Defined as a history of stroke, myocardial infarction, coronary heart disease, or angina. Unweighted total number of cases of cardiovascular disease is 476,227.

<sup>b</sup> Significant at  $P < .05$ ; determined by permutation test for joinpoint regression.

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Characteristic	Age-adjusted prevalence, %		Average annual percentage change (95% CI)	Annual percentage change (95% CI)		
	2011	2020	2011–2020	Trend segment 1, 2011–2015	Trend segment 2, 2015–2018	Trend segment 3, 2018–2020
Unmarried	37.8	40.1	1.3 (–3.6 to 6.4)	–1.5 (–15.8 to 15.3)	–0.6 (–14.5 to 15.6)	9.5 (–19.1 to 48.2)
Divorced/widowed/separated	36.6	38.3	1.1 (–0.9 to 3.1)	2.9 (–0.2 to 6.1)	–6.1 (–15.3 to 4.0)	9.1 (–1.5 to 20.9)
<b>Health insurance</b>						
No	22.7	24.5	1.6 (–5.4 to 9.1)	0.7 (–10.0 to 12.6)	–4.2 (–33.6 to 38.1)	12.8 (–23.0 to 65.2)
Yes	43.0	48.2	1.5 (–0.7 to 3.8)	0.1 (–3.3 to 3.4)	–4.7 (–15.1 to 7.1)	15.2 (2.9 to 28.9) <sup>b</sup>
<b>Diabetes</b>						
No	36.6	42.0	1.9 (0.8 to 3.0) <sup>b</sup>	0.9 (–0.7 to 2.6)	–4.4 (–9.5 to 1.0)	14.2 (8.2 to 20.6) <sup>b</sup>
Yes	46.2	52.1	1.7 (–0.4 to 4.0)	1.8 (–1.7 to 5.3)	–6.4 (–16.6 to 5.0)	15.2 (3.5 to 28.3) <sup>b</sup>
<b>Obesity (body mass index &gt;30.0)</b>						
No	38.0	42.3	1.8 (–1.1 to 4.8)	0.5 (–3.7 to 4.9)	–3.7 (–17.1 to 11.9)	13.6 (–2.1 to 31.8)
Yes	40.2	46.6	1.8 (–2.9 to 6.8)	1.4 (–5.9 to 9.2)	–5.0 (–25.6 to 21.3)	13.9 (–11.6 to 46.7)
<b>Cigarette use</b>						
Never	41.1	45.9	1.9 (0.1 to 3.8) <sup>b</sup>	0.3 (–2.7 to 3.5)	–3.6 (–12.7 to 6.4)	14.1 (4.1 to 25.1) <sup>b</sup>
Former	41.5	48.7	1.9 (0.6 to 3.2) <sup>b</sup>	1.2 (–0.8 to 3.2)	–5.2 (–10.9 to 0.8)	15.1 (7.5 to 23.2) <sup>b</sup>
Current	32.1	35.9	1.4 (–5.2 to 8.4)	1.7 (–7.2 to 11.5)	–6.2 (–34.2 to 33.6)	13.2 (–20.3 to 60.8)
<b>Has a personal health care provider</b>						
No	23.5	26.1	1.8 (–2.4 to 6.2)	0.3 (–6.3 to 7.5)	–6.6 (–25.0 to 16.5)	19.2 (–3.4 to 47.0)
Yes	42.1	47.9	1.8 (0.1 to 3.4) <sup>b</sup>	1.0 (–1.5 to 3.5)	–4.2 (–12.0 to 4.3)	13.2 (4.1 to 23.1) <sup>b</sup>
<b>Time since most recent visit to personal health care provider for routine checkup</b>						
Within last year	42.7	48.8	1.7 (0.2 to 3.2) <sup>b</sup>	1.1 (–1.1 to 3.4)	–5.0 (–12.1 to 2.7)	14.1 (6.0 to 22.7) <sup>b</sup>
1–2 Years since last visit	30.7	29.4	–0.1 (–10.2 to 11.1)	1.9 (–13.7 to 20.3)	–8.6 (–4.9 to 17.2)	9.5 (–7.0 to 27.1)
>2 Years since last visit	25.8	20.1	–2.3 (–6.5 to 2.2)	0.4 (–5.8 to 7.0)	–11.9 (–28.3 to 8.3)	8.2 (–19.0 to 34.5)

<sup>a</sup> Defined as a history of stroke, myocardial infarction, coronary heart disease, or angina. Unweighted total number of cases of cardiovascular disease is 476,227.

<sup>b</sup> Significant at  $P < .05$ ; determined by permutation test for joinpoint regression.

**Table 2. Predictors of Influenza Vaccination Among US Adults With Cardiovascular Disease, Behavioral Risk Factor Surveillance System, January 2011–December 2020<sup>a</sup>**

Characteristic	Pooled model	Year fixed-effects model <sup>b</sup>	Year–state fixed-effects model <sup>c</sup>
<b>Age, y</b>			
18–44	1 [Reference]	1 [Reference]	1 [Reference]
45–64	1.49 <sup>d</sup> (1.40–1.60)	1.49 <sup>d</sup> (1.39–1.59)	1.50 <sup>d</sup> (1.41–1.61)
≥65	2.54 <sup>d</sup> (2.37–2.73)	2.53 <sup>d</sup> (2.36–2.71)	2.58 <sup>d</sup> (2.40–2.76)
<b>Sex</b>			
Female	1.06 <sup>d</sup> (1.03–1.09)	1.06 <sup>d</sup> (1.03–1.09)	1.06 <sup>d</sup> (1.03–1.10)
Male	1 [Reference]	1 [Reference]	1 [Reference]
<b>Race</b>			
American Indian/Alaska Native, non-Hispanic	0.87 <sup>e</sup> (0.77–1.00)	0.87 <sup>e</sup> (0.76–0.99)	0.86 <sup>e</sup> (0.75–0.98)
Asian, non-Hispanic	1.14 (0.93–1.41)	1.17 (0.96–1.44)	1.21 (0.98–1.50)
Black/African American, non-Hispanic	0.73 <sup>d</sup> (0.70–0.77)	0.73 <sup>d</sup> (0.69–0.77)	0.73 <sup>d</sup> (0.70–0.77)
Hispanic	0.77 <sup>d</sup> (0.72–0.82)	0.77 <sup>d</sup> (0.72–0.82)	0.96 (0.88–1.04)
Native Hawaiian/Pacific Islander, non-Hispanic	0.93 (0.75–1.14)	0.90 (0.73–1.11)	0.91 (0.73–1.12)
White, non-Hispanic	1 [Reference]	1 [Reference]	1 [Reference]
Other, non-Hispanic	0.84 <sup>d</sup> (0.77–0.92)	0.84 <sup>d</sup> (0.76–0.92)	0.84 <sup>d</sup> (0.76–0.92)
<b>Education</b>			
Some high school or less	1 [Reference]	1 [Reference]	1 [Reference]
High school graduate	1.07 <sup>f</sup> (1.03–1.13)	1.07 <sup>f</sup> (1.02–1.13)	1.08 <sup>f</sup> (1.03–1.13)
Some college or technical school	1.16 <sup>d</sup> (1.10–1.22)	1.16 <sup>d</sup> (1.11–1.22)	1.18 <sup>d</sup> (1.12–1.24)
College graduate	1.38 <sup>d</sup> (1.31–1.46)	1.38 <sup>d</sup> (1.31–1.46)	1.42 <sup>d</sup> (1.34–1.50)
<b>Annual household income, \$</b>			
<50,000	1 [Reference]	1 [Reference]	1 [Reference]
≥50,000	1.04 <sup>e</sup> (1.01–1.08)	1.04 <sup>e</sup> (1.01–1.08)	1.03 (1.00–1.07)
<b>Marital status</b>			
Married	1 [Reference]	1 [Reference]	1 [Reference]
Unmarried	0.99 (0.93–1.05)	0.98 (0.93–1.04)	0.99 (0.93–1.05)
Divorced/widowed/separated	0.94 <sup>d</sup> (0.91–0.97)	0.94 <sup>d</sup> (0.91–0.97)	0.94 <sup>d</sup> (0.91–0.97)
<b>Diabetes</b>			
Yes	1.29 <sup>d</sup> (1.24–1.33)	1.29 <sup>d</sup> (1.25–1.33)	1.29 <sup>d</sup> (1.25–1.33)
No	1 [Reference]	1 [Reference]	1 [Reference]
<b>Obesity (body mass index &gt;30.0)</b>			
Yes	1.02 (0.99–1.05)	1.02 (0.99–1.05)	1.01 (0.98–1.04)
No	1 [Reference]	1 [Reference]	1 [Reference]

<sup>a</sup> All values are adjusted odds ratios (95% CI) from a multivariate model that simultaneously estimated effects for all demographic, socioeconomic, health care, and cardiovascular disease factors listed in table.

<sup>b</sup> Multivariate model adjusted for years as indicator variable (result not shown for years indicator).

<sup>c</sup> Multivariate model additionally adjusted for states as indicator variable (result not shown for states indicator).

<sup>d</sup> Significant at  $P < .001$ ; determined by 2-sided z test.

<sup>e</sup> Significant at  $P < .05$ ; determined by 2-sided z test.

<sup>f</sup> Significant at  $P < .01$ ; determined by 2-sided z test.

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**Table 2. Predictors of Influenza Vaccination Among US Adults With Cardiovascular Disease, Behavioral Risk Factor Surveillance System, January 2011–December 2020<sup>a</sup>**

Characteristic	Pooled model	Year fixed-effects model <sup>b</sup>	Year–state fixed-effects model <sup>c</sup>
<b>Cigarette use</b>			
Never	1 [Reference]	1 [Reference]	1 [Reference]
Former	1.15 <sup>d</sup> (1.11–1.19)	1.15 <sup>d</sup> (1.11–1.19)	1.15 <sup>d</sup> (1.11–1.19)
Current	0.81 <sup>d</sup> (0.77–0.84)	0.80 <sup>d</sup> (0.77–0.84)	0.79 <sup>d</sup> (0.76–0.83)
<b>Health insurance</b>			
Yes	1.71 <sup>d</sup> (1.59–1.84)	1.72 <sup>d</sup> (1.60–1.85)	1.76 <sup>d</sup> (1.63–1.89)
No	1 [Reference]	1 [Reference]	1 [Reference]
<b>Has a primary care provider</b>			
Yes	1.71 <sup>d</sup> (1.60–1.83)	1.70 <sup>d</sup> (1.59–1.82)	1.71 <sup>d</sup> (1.60–1.83)
No	1 [Reference]	1 [Reference]	1 [Reference]
<b>Time since most recent visit to primary care provider for routine checkup</b>			
Within last year	1 [Reference]	1 [Reference]	1 [Reference]
1 or 2 years	0.65 <sup>d</sup> (0.61–0.69)	0.64 <sup>d</sup> (0.60–0.68)	0.63 <sup>d</sup> (0.60–0.67)
>2 years	0.54 <sup>d</sup> (0.50–0.57)	0.53 <sup>d</sup> (0.50–0.56)	0.52 <sup>d</sup> (0.49–0.56)

<sup>a</sup> All values are adjusted odds ratios (95% CI) from a multivariate model that simultaneously estimated effects for all demographic, socioeconomic, health care, and cardiovascular disease factors listed in table.

<sup>b</sup> Multivariate model adjusted for years as indicator variable (result not shown for years indicator).

<sup>c</sup> Multivariate model additionally adjusted for states as indicator variable (result not shown for states indicator).

<sup>d</sup> Significant at  $P < .001$ ; determined by 2-sided z test.

<sup>e</sup> Significant at  $P < .05$ ; determined by 2-sided z test.

<sup>f</sup> Significant at  $P < .01$ ; determined by 2-sided z test.

Appendix. Supplemental Tables and Figure

Appendix. Supplemental Table 1. Characteristics of US Adults, by Cardiovascular Disease Status, Behavioral Risk Factor Surveillance System, January 2011–December 2020<sup>a</sup>

Characteristic	No CVD		CVD		Total	
	Unweighted no.	Weighted %	Unweighted no.	Weighted %	Unweighted no.	Weighted %
All	3,654,187	91.5	476,427	8.5	4,130,414	100.0
<b>Age, y</b>						
18–44	1,112,673	49.4	23,245	10.8	1,135,918	46.1
45–64	1,438,502	33.7	150,588	38.0	1,589,090	34.1
≥65	1,103,012	16.9	302,394	51.2	1,405,406	19.8
<b>Sex</b>						
Male	1,517,785	47.8	238,302	55.4	1,756,087	48.5
Female	2,135,465	52.2	237,772	44.6	2,373,237	51.5
<b>Race and ethnicity</b>						
American Indian/Alaska Native, non-Hispanic	58,553	1.6	8,448	1.6	67,001	1.6
Asian, non-Hispanic	66,264	4.1	3,397	1.6	69,661	3.9
Black/African American, non-Hispanic	275,094	11.3	38,207	11.7	313,301	11.3
Hispanic	296,619	16.5	25,200	11.0	321,819	16.0
Native Hawaiian/Pacific Islander, non-Hispanic	21,847	0.4	2,976	0.5	24,823	0.4
White, non-Hispanic	2,790,330	64.3	376,006	71.5	3,166,336	64.9
Other, non-Hispanic	89,646	1.8	13,642	2.1	103,288	1.8
<b>Education</b>						
Some high school or less	248,649	12.7	59,534	20.9	308,183	13.4
High school graduate	984,246	27.6	15,6517	31.1	1,140,763	27.9
Some college or technical school	1,007,445	31.3	133,671	30.0	1,141,116	31.2
College graduate	1,404,200	28.5	125,265	18.0	1,529,465	27.6
<b>Annual household income, \$</b>						
<50,000	1,567,178	50.4	282,137	69.4	1,849,315	52.0
≥50,000	1,561,583	49.6	118,083	30.6	1,679,666	48.0
<b>Marital status</b>						
Married	1,954,282	51.1	220,467	51.0	2,174,749	51.1
Unmarried	722,808	30.4	42,869	12.0	765,677	28.9
Divorced/widowed/separated	956,241	18.5	211,030	37.0	1,167,271	20.0
<b>Health insurance</b>						
No	341,962	14.3	25,099	8.2	367,061	13.8
Yes	3,299,072	85.7	449,914	91.8	3,748,986	86.2
<b>Diabetes</b>						
No	3,225,377	90.3	325,384	68.3	3,550,761	88.4

<sup>a</sup> Proportions of adults with CVD and no CVD were significantly different for each characteristic at  $P < .001$ .

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**Appendix. Supplemental Table 1. Characteristics of US Adults, by Cardiovascular Disease Status, Behavioral Risk Factor Surveillance System, January 2011–December 2020<sup>a</sup>**

Characteristic	No CVD		CVD		Total	
	Unweighted no.	Weighted %	Unweighted no.	Weighted %	Unweighted no.	Weighted %
Yes	423,215	9.7	149,878	31.7	573,093	11.6
<b>Obesity (body mass index &gt;30.0)</b>						
No	2,430,686	71.2	290,509	62.0	2,721,195	70.4
Yes	1,010,597	28.8	167,847	38.0	1,178,444	29.6
<b>Cigarette use</b>						
Never	2,119,576	60.5	192,941	39.5	2,312,517	58.7
Former	979,931	23.0	197,128	40.2	1,177,059	24.5
Current	535,034	16.5	83,321	20.4	618,355	16.8
<b>Has a personal health care provider</b>						
No	609,553	23.4	31,179	9.0	640,732	22.2
Yes	3,030,944	76.6	443,358	91.0	3,474,302	77.8
<b>Time since most recent visit to personal health care provider for routine checkup</b>						
Within last year	2,666,863	69.7	410,628	85.8	3,077,491	71.1
1–2 Years	431,127	13.5	29,663	6.8	460,790	12.9
>2 Years	514,065	16.8	29,912	7.4	543,977	16.0

<sup>a</sup> Proportions of adults with CVD and no CVD were significantly different for each characteristic at  $P < .001$ .

**Appendix. Supplemental Table 2. Trends in Prevalence of Annual Influenza Vaccination Among US Adults With Cardiovascular Disease, Behavioral Risk Factor Surveillance System, January 2011–December 2020<sup>a</sup>**

Characteristic	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>No.</b>	52,122	51,197	50,500	49,612	43,563	53,147	45,522	47,791	42,880	39,893
<b>Cardiovascular disease</b>										
Any cardiovascular disease <sup>b</sup>	38.6	38.5	38.9	38.5	39.4	38.3	39.3	32.1	40.4	44.3
Angina/coronary heart disease only	39.1	39.3	40.0	38.1	40.3	40.1	40.4	37.2	42.4	46.9
Stroke only	38.6	36.2	38.0	39.5	38.8	36.9	39.7	31.7	40.2	42.9
Myocardial infarction only	32.8	37.7	35.8	34.5	37.1	34.8	37.0	28.2	37.1	40.1
≥2 Cardiovascular diseases	43.5	40.2	42.6	40.9	40.7	41.9	39.4	31.6	41.7	46.6
<b>Age, y</b>										
18–44	27.5	25.9	27.0	27.6	27.6	29.1	28.2	21.6	29.0	33.3
45–64	42.7	45.1	43.6	42.6	45.0	40.3	43.6	36.0	44.8	48.1
≥65	61.4	60.3	62.7	60.8	60.9	59.9	61.5	53.6	63.6	67.5
<b>Sex</b>										
Male	36.4	37.2	37.4	37.8	38.3	34.7	38.5	30.9	37.9	41.8
Female	41.1	39.9	40.5	39.3	40.6	42.4	40.2	33.5	43.0	47.2
<b>Race and ethnicity</b>										
American Indian/Alaska Native, non-Hispanic	41.4	58.3	37.4	37.3	40.9	36.3	31.8	25.3	42.5	40.3
Asian, non-Hispanic	34.6	41.4	36.3	44.1	39.0	51.5	54.5	38.3	60.1	50.4
Black/African American, non-Hispanic	36.2	32.6	36.3	36.3	39.1	37.1	35.2	31.0	39.8	43.3
Hispanic	33.9	32.7	33.5	32.4	34.7	34.2	35.2	30.5	33.2	36.8
Native Hawaiian/Pacific Islander, non-Hispanic	39.7	36.6	34.0	36.9	19.1	42.8	38.6	23.8	49.8	46.1
White, non-Hispanic	39.7	40.3	40.6	40.6	40.6	38.8	40.2	31.7	41.4	46.3
Other, non-Hispanic	36.7	40.0	44.5	37.7	33.3	29.9	46.6	32.7	36.6	40.4
<b>Education</b>										
Some high school or less	32.5	33.9	35.0	34.6	32.9	37.6	32.0	28.3	31.7	36.2
High school graduate	37.5	37.8	38.0	35.9	36.8	33.5	39.8	30.7	38.7	41.0
Some college or technical school	40.4	39.6	39.6	40.3	41.3	38.8	40.4	31.9	44.4	44.2
College graduate	46.2	44.4	45.2	45.3	49.1	47.9	46.7	39.5	46.8	59.1
<b>Annual household income, \$</b>										
<50,000	36.7	38.1	38.1	37.2	37.0	37.0	37.6	29.8	40.2	41.8
≥50,000	44.5	41.3	42.8	44.4	47.1	44.7	43.0	35.9	43.4	49.7
<b>Marital status</b>										
Married	39.9	40.3	41.4	41.7	41.1	40.3	40.0	33.3	41.7	50.0
Unmarried	37.8	36.7	38.3	34.0	37.0	35.0	38.9	30.9	41.6	40.1
Divorced/widowed/separated	36.6	35.8	35.8	36.6	38.9	40.0	37.3	29.5	36.3	38.3

<sup>a</sup> All estimates were age-standardized based on the 2010 US Census population, by reported age groups. All percentages were weighted.

<sup>b</sup> Any cardiovascular disease was defined as a history of stroke, myocardial infarction, coronary heart disease, or angina. Unweighted total number of cases of cardiovascular disease = 476,227.

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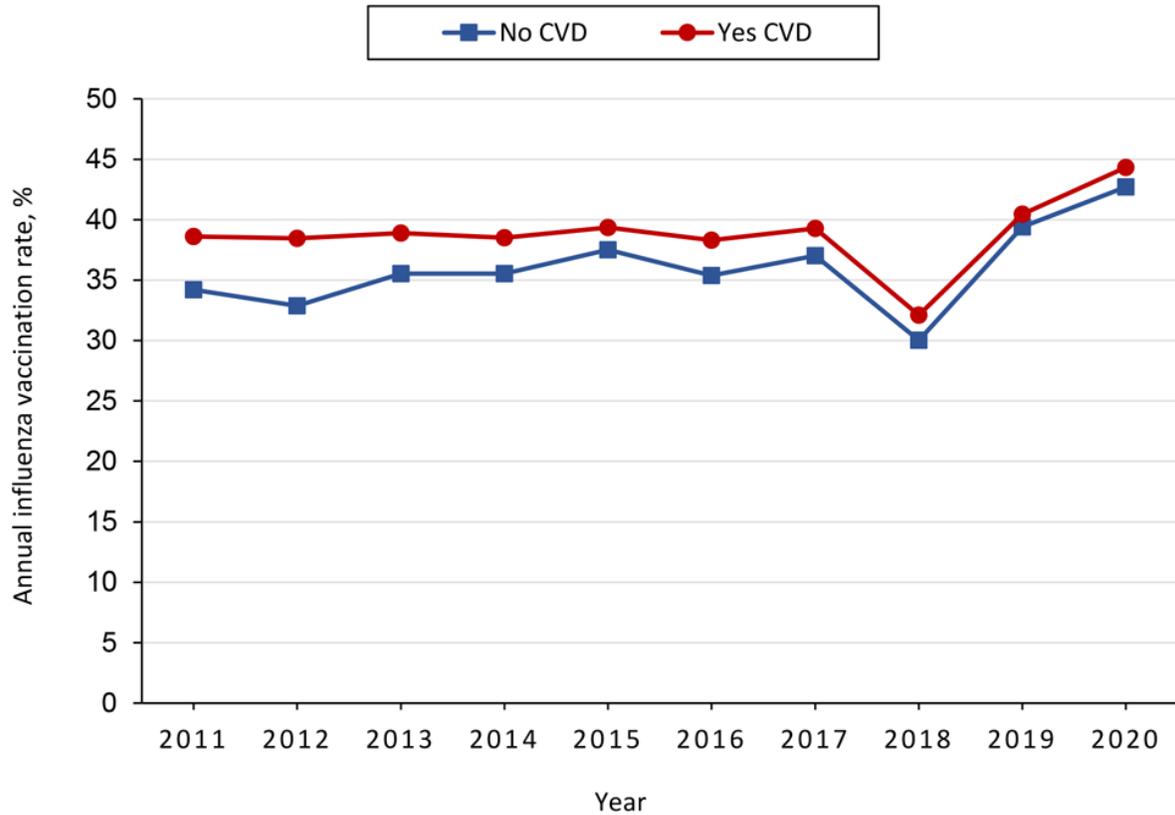
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**Appendix. Supplemental Table 2. Trends in Prevalence of Annual Influenza Vaccination Among US Adults With Cardiovascular Disease, Behavioral Risk Factor Surveillance System, January 2011–December 2020<sup>a</sup>**

Characteristic	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>Health insurance</b>										
No	22.7	24.3	21.4	21.3	24.2	23.0	23.7	17.2	25.6	24.5
Yes	43.0	41.6	42.8	42.1	41.7	40.5	42.0	34.2	43.2	48.2
<b>Diabetes</b>										
No	36.6	36.2	36.8	36.5	37.2	36.3	36.6	30.6	38.5	42.0
Yes	46.2	44.9	45.8	46.6	48.6	44.5	48.1	36.6	46.2	52.1
<b>Obesity (body mass index &gt;30.0)</b>										
No	38.0	38.0	36.4	37.6	38.5	36.4	38.8	31.1	40.7	42.3
Yes	40.2	39.0	42.9	41.0	40.6	40.9	40.1	34.1	40.9	46.6
<b>Cigarette use</b>										
Never	41.1	40.0	38.9	39.4	40.4	39.8	40.6	33.0	43.4	45.9
Former	41.5	42.7	42.5	44.2	43.1	41.0	42.0	35.5	43.8	48.7
Current	32.1	31.6	34.9	32.3	33.4	32.1	33.8	25.8	31.9	35.9
<b>Has a personal health care provider</b>										
No	23.5	21.8	23.0	22.6	24.4	20.2	22.1	17.9	23.1	26.1
Yes	42.1	41.3	42.5	42.5	42.0	42.2	43.1	34.8	44.3	47.9
<b>Time since most recent visit to personal health care provider for routine checkup</b>										
Within last year	42.7	43.3	43.4	42.6	44.0	42.3	44.4	35.0	44.5	48.8
1–2 Years	30.7	27.7	30.4	33.0	30.5	28.0	29.4	21.1	25.3	29.4
>2 Years	25.8	23.8	24.3	22.6	23.6	24.9	21.4	14.1	17.6	20.1

<sup>a</sup> All estimates were age-standardized based on the 2010 US Census population, by reported age groups. All percentages were weighted.

<sup>b</sup> Any cardiovascular disease was defined as a history of stroke, myocardial infarction, coronary heart disease, or angina. Unweighted total number of cases of cardiovascular disease = 476,227.



**Appendix.** Supplementary Figure. Influenza vaccination rates among US adults, by cardiovascular disease status, Behavioral Risk Factor Surveillance System, January 2011–December 2020.

## ORIGINAL RESEARCH

# A Qualitative Study of Perceptions, Strengths, and Opportunities in Cardiometabolic Risk Management During Pregnancy and Postpartum in a Georgia Safety-Net Hospital, 2021

Kaitlyn K. Stanhope, PhD, MPH<sup>1</sup>; Anna Newton Levinson, PhD, MPH<sup>2</sup>; C. Taé Stallworth, LPN<sup>1</sup>; Sophie Leruth, MPH<sup>2</sup>; Emma Clevenger, MPH<sup>2</sup>; Margaret Master, MBA, MPH<sup>2</sup>; Anne L. Dunlop, MD, MPH<sup>1</sup>; Sheree L. Boulet, DrPH, MPH<sup>1</sup>; Denise J. Jamieson, MD, MPH<sup>1</sup>; Sarah Blake, PhD, MA<sup>2</sup>

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## PEER REVIEWED

**Summary****What is already known about this topic?**

Hypertension and diabetes during pregnancy are associated with increased heart disease risk. Less than one-half of the people with hypertension or diabetes during pregnancy receive guideline-compliant postpartum care.

**What is added by this report?**

Postpartum participants described barriers to managing and monitoring high-risk conditions postpartum, including competing priorities, such as finances, and lack of obstetric or gynecologic knowledge.

**What are the implications for public health practice?**

Additional support from the obstetric care team may improve postpartum care engagement for obstetric patients in a Medicaid-insured, safety-net population.

## Abstract

**Introduction**

Despite the strong link between cardiometabolic pregnancy complications and future heart disease, there are documented gaps in engaging those who experience such conditions in recommended postpartum follow-up and preventive care. The goal of our study

was to understand how people in a Medicaid-insured population perceive and manage risks during and after pregnancy related to an ongoing cardiometabolic disorder.

**Methods**

We conducted in-depth qualitative interviews with postpartum participants who had a cardiometabolic conditions during pregnancy (chronic or gestational diabetes, chronic or gestational hypertension, or preeclampsia). We recruited postpartum participants from a single safety-net hospital system in Atlanta, Georgia, and conducted virtual interviews during January through May 2021. We conducted a content analysis guided by the Health Belief Model and present themes related to risk management.

**Results**

From the 28 interviews we conducted, we found that during pregnancy, advice and intervention by the clinical care team facilitated management behaviors for high-risk conditions. However, participants described limited understanding of how pregnancy complications might affect future outcomes, and few described engaging in postpartum management behaviors.

**Conclusion**

Improving continuity and content of care during postpartum may improve uptake of preventive behaviors among postpartum patients at risk of heart disease.

## Introduction

Cardiometabolic health conditions are critical determinants of perinatal risk. Pregnant women with chronic diabetes or hypertension are at increased risk of infant and maternal morbidity (1–3). Additionally, incident cardiometabolic dysfunction during pregnancy



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(eg, gestational hypertension, preeclampsia, or gestational diabetes) is associated with elevated perinatal risk (2). Pregnant women with incident or chronic cardiometabolic dysfunction require monitoring during pregnancy to prevent and mitigate potential adverse outcomes (4–6).

After delivery, women who experienced cardiometabolic dysfunction during pregnancy are at elevated risk of severe maternal morbidity, postpartum complications, and future development of cardiovascular disease, diabetes, and hypertension (7–9). To detect and prevent complications, the obstetric care team should screen postpartum patients for ongoing hypertension or glucose intolerance in the postpartum period, counsel them on heart disease risk and prevention, and refer them to primary care for ongoing surveillance and management (10). However, less than one-half of patients with cardiometabolic complications of pregnancy receive guideline-concordant postpartum blood pressure or glucose screening (11–13).

Engagement in beneficial postpartum health behaviors can mitigate risks related to cardiometabolic conditions. Returning to or attaining a healthy weight, lactation, and control of glucose and blood pressure are evidence-based strategies to reduce future heart disease risk and might also reduce risk in a future pregnancy (14–16). If patients are unaware of their heart disease risk or prevention strategies, however, they may be less likely to engage in optimal behaviors. Limited data suggest that people have limited knowledge about the link between pregnancy complications and future disease risk (17–19).

Limited data exist on patient understanding and management of cardiometabolic risks during pregnancy, particularly in Medicaid-insured low-income populations, in which maternal morbidity and mortality are highest (20). By using the Health Belief Model (21), we sought to understand how (22), our study's goal was to understand how postpartum participants perceive and manage risks related to an ongoing cardiometabolic disorder during and after pregnancy.

## Methods

### Study design

Our study consisted of in-depth interviews with low-income postpartum patients at a safety-net hospital in Georgia and was part of a larger study to develop, implement, and test a postpartum planning intervention for patients at high risk of severe maternal morbidity. We received approval for this study from the Emory University Institutional Review Board (STUDY00001427).

### Participants

Patients for this study were recruited from a single safety-net hospital system in Atlanta, Georgia, (Grady Hospital) and were eligible if they 1) were within 3 to 6 months postpartum after delivering a liveborn infant from October 2020 through January 2021; 2) received prenatal care in the Grady Health System; and 3) had a prenatal diagnosis of diabetes, chronic hypertension, a hypertensive disorder of pregnancy (HDP), inclusive of gestational hypertension or preeclampsia, or gestational diabetes. We identified potentially eligible patients through diagnostic codes in the electronic medical records and contacted them by telephone to invite them to participate. We conducted purposive sampling of postpartum participants who both had and had not attended their postpartum visit. Interviews were conducted during January through May 2021. Participants provided written informed consent before participating and were given a \$50 gift card after interview completion.

### Data collection

We developed a semistructured interview guide to assess how patients understood and managed cardiometabolic risk conditions during pregnancy and postpartum (Table 1). After developing a draft of the guide, we shared it with members of our community advisory board, which consisted of local maternal health leaders, and revised the language according to board feedback. We then piloted the guide with 3 initial interviews, making slight modifications to language, and developed probes after each pilot interview.

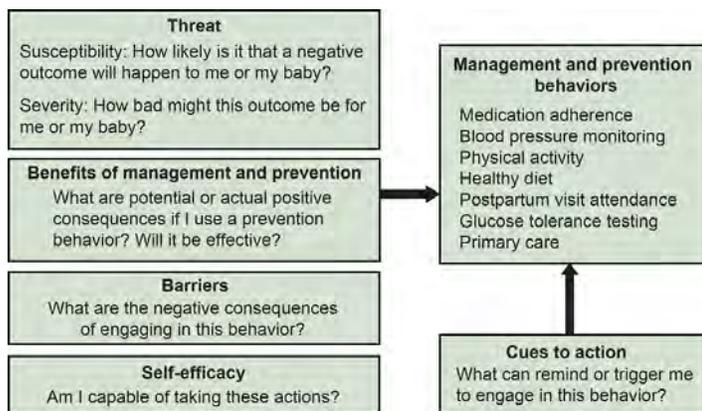
Interviews lasted an average of 78 minutes and were conducted by using Zoom. One or 2 trained study team members conducted each interview, and a team member took detailed notes. Interviews were recorded with the permission of the participant.

### Analysis

All interview recordings were professionally transcribed. We used MAXQDA (VERBI GmbH Berlin) for data management and transcript analysis (23). A directed content approach for coding data was guided by research questions (24). We developed a codebook by using a team-based approach in which all members read an initial 5 transcripts, wrote analytic notes with initial interpretations of the text, and developed candidate deductive and inductive codes. We applied the initial codebook to transcripts in teams of 2 and iteratively updated the codebook to produce a final codebook that was applied to the remaining data. Further identification of patterns across and within data were used to develop themes during a final stage of interpretation.

**Theoretical framework**

We used the Health Belief Model to organize and interpret thematic results about participant management of pregnancy and chronic disease during pregnancy and postpartum and presented key themes by element of the Health Belief Model and timing (pregnancy or postpartum) (Figure). A study team member mapped and coded segments related to understanding and managing cardiometabolic risk conditions and general health to applicable elements of the Health Belief Model (threat, benefits, barriers, self-efficacy, and cues to action) and identified patterns across and within data to develop themes.



**Figure.** Diagram of the constructs of the Health Belief Model (22), as applied to the current study of high-risk cardiometabolic conditions during pregnancy and postpartum, adapted from (24).

Health Belief Model asserts that people make choices about their health risk behaviors depending on their perceived susceptibility to an adverse outcome, their perceived severity of the outcome, and their perceived benefits from and barriers to a given behavior (22,24). Perceived self-efficacy and external cues to action facilitate uptake of health-promoting behaviors. This framework helps identify possible opportunities for health care providers to improve patient support systems for managing cardiometabolic risk conditions.

**Results**

Of the 93 postpartum participants identified as potentially eligible through electronic medical records, 28 (30%) completed an interview. By design, all study participants had 1 or more cardiometabolic risk conditions complicating pregnancy as recorded in the medical record (Table 2). Fifteen (54%) had hypertension. An additional 12 (43%) had a gestational hypertension diagnosis. Many (13, 46%) of those with gestational or chronic hypertension developed preeclampsia. Diabetes was rare, only occurring in 2 par-

ticipants. Six (21%) participants had gestational diabetes. Most participants (19, 68%) had at least 1 previous pregnancy, 24 (86%) identified as non-Hispanic Black, and 26 (93%) were insured by Medicaid during pregnancy. Participants ranged in age from 18 years to 42 years, with a median age of 27 years.

**Thematic findings**

**Perceived susceptibility**

Perceived susceptibility is a person’s belief of how probable or improbable a given adverse outcome is for them. We considered beliefs about susceptibility to be both the participant’s understanding of their pregnancy-related diagnosis and their perception of their risk for future adverse outcomes.

Almost all participants understood that they had a cardiometabolic risk condition during pregnancy (Table 3); however, understanding of their specific diagnosis varied. Although all participants with diabetes or gestational diabetes understood their diagnosis, 9 of 16 participants with HDP were unclear about their exact diagnosis. For example, one participant with HDP explained that her blood pressure was not of concern until a spike immediately before her pregnancy. Another one explained, “Since it wasn’t always persistent on high . . . next visit it would be a little bit lower. Then it’ll be high . . . About the last month is when it started staying consistent. So that’s when they was like, ‘Oh, I think we going to have to get him out ASAP.’”

Most (12 of 16) participants with HDP or gestational diabetes in the postpartum period believed their condition was no longer an issue. Additionally, 5 of 15 participants with hypertension were unconcerned about their blood pressure, stating that it was high during pregnancy but not otherwise of concern (Table 3). “They tried to give me some blood pressure meds, and I told them, ‘it’s normal, it will go away in due time.’ I know my body because that’s what happened with the last one,” one participant with hypertension said.

Patients who attended the postpartum visit (attendees) and those who did not (nonattenders) described similar concerns about complications, primarily about infant complications. However, 2 of 16 attendees described discussions with the postpartum visit provider about hypertension that helped them understand their own risk.

**Perceived severity**

Perceived severity is a person’s perception of potential danger from a given disease or an adverse outcome. We focused on participants’ perceptions of adverse consequences of their cardiometabolic disease diagnosis. Many (13 of 28) participants were concerned about risks to the developing fetus, such as a miscarriage or preterm birth, because of their cardiometabolic risk condition. A

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nonattender with gestational diabetes said, “Mainly, [gestational diabetes] can affect [the baby]. Sometimes, baby come out real, real small. Sometimes, people have miscarriage, [because of] it, and sometimes, your baby can come out real, real big.”

In contrast, 6 of 28 nonattender participants expressed concern over risks to their own health, primarily describing possible strokes either during labor or at any time. A nonattender with HDP said, “Because I was getting to the point where I could have had a stroke, a seizure, heart attack, because all that anger and my blood pressure . . . the doctor said just go ahead and induce [me]. Because if they leave the baby in there, it could either come to the baby or my life. So, I was like, wow. I started crying when she told me that, because I was like, I’m going to die.”

After pregnancy, 4 of 16 participants described concern about potential risk because of gestational diabetes or HDP. Eight of 15 participants with hypertension and diabetes expressed understanding of their continued risk, although this was not true for participants who believed their hypertension to be relevant only during pregnancy. Both postpartum visit attendees and nonattenders described similar levels of concern about high-risk conditions during pregnancy, primarily for the baby. Slightly more attendees (7 of 16) than nonattenders (4 of 12) described concerns for future risks.

### **Perceived benefits**

Perceived benefits are perceived or actual positive consequences resulting from a given health behavior. During pregnancy, 6 of 28 participants described engaging in specific behaviors to prevent adverse infant outcomes or to optimize their own health during pregnancy by managing weight gain and glucose levels. Perceived healthy behaviors included glucose and blood pressure monitoring, insulin injections, and exercise. One participant with diabetes and HDP explained, “I mean, diet is a main thing and exercise. . . I walked like 30 minutes to 40 minutes every day. . . Yeah. It helps, because whenever I test on home, the sugar level was perfect, and on every visit, they saw the sugar level and all that, that I tested. So, it was good, and they told me to do the same thing, like diet, exercise.”

During the postpartum period, some participants described engaging in prevention behaviors such as following up with primary care, maintaining a healthy diet, and exercising to stay healthy and to take care of children. An attendee with hypertension explained, “I’m 26 now and I had my first child when I was 19, so when I was younger, I wasn’t thinking about stuff like that [primary care visits]. But now that I had the hypertension when I was pregnant and I’m getting older, I feel like I need to focus on that because I want to be here to see my kids grow up.”

A few (5 of 28) participants exercised, dieted, or followed up with primary care specifically to lose weight. A nonattender explained, “That was another thing, my weight. Oh, my goodness. I was not happy and I’m still not happy, but I joined the gym.” One participant described engaging in healthy behaviors (exercise, diet, and smoking cessation) to prevent heart disease (Table 3). Postpartum visit attendees and nonattenders described similar perceived benefits to prevention behaviors during and after pregnancy. However, more attendees (11 of 16) than nonattenders (3 of 12) described plans to engage in primary care following pregnancy.

### **Perceived barriers**

Perceived barriers are perceived or negative consequences of a given behavior or costs associated with that behavior. During pregnancy, participants described medication side effects and costs as barriers to engaging in blood pressure monitoring or medication use. An attending participant with hypertension said, “They tried to give me some blood pressure meds, and I told them, ‘It’s normal,’ it will go away in due time. . . I’m not going to take it because it made me feel nauseous and it tires me even more than what I am.”

During postpartum, 6 of 28 participants identified childcare as a barrier to self-care, or participants prioritized their children’s needs over their own, which limited their ability to engage in self-care behaviors or to seek follow-up care. A nonattender with hypertension needed to remain at home to care for her preterm infant with a feeding tube, although her care team asked her to return to the hospital for readmission because of her dangerously high blood pressure, as measured at a home visit. “Just because of how high they said [my blood pressure] was that day, but I think he was still on the feeding tube at that time, so my other children, they don’t know how to change a feeding tube. It was just, I couldn’t go [to be readmitted] at that time.”

Additionally, 5 of 28 postpartum participants explained how financial and insurance barriers prevented them from attending needed follow-up for primary or specialty care after their pregnancy. Participants were limited in their choice of providers, because some providers did not accept Medicaid or uninsured patients. Primary care practices that accepted Medicaid had limited availability, and participants were often unable to find an available appointment. Other participants described similar barriers to engaging in prevention behaviors during and after pregnancy. Two nonattenders at postpartum visits described mistrust of doctors as a barrier to seeking primary care.

### **Cues to action**

Cues to action are reminders or triggers to engage in health-promoting behaviors when a person is ready. During pregnancy, cues to action stemmed primarily from counseling, reminders, or

check-ins from the clinical care team. For example, participants with diabetes or gestational diabetes reported receiving support through one-on-one counseling and check-ins with a trained nurse and materials and guidance on testing blood glucose. This counseling helped remind participants to monitor glucose levels. In contrast, participants with hypertension or HDP largely created their own systems for reminding themselves to take medication (eg, pill organizers, alarms). One attending participant with gestational diabetes and hypertension explained, “Mainly what I did for myself was to try to set an alarm so that we know it’s time to check your blood pressure, . . . and I bought a pill organizer so I can keep my medicine by my bed and wake up and have the medicines right there.”

After pregnancy, participants described few cues to action from the clinical care team to support heart health behaviors. Despite explicit probes, only 8 of 16 reported discussing relevant healthy behaviors at the postpartum visit. For example, in one interview, the interviewer asked if the attending participant with HDP was asked about blood pressure at all at her postpartum visit and if [the clinician] was aware that the participant had high blood pressure during pregnancy. The participant indicated a negative response and stated, “They don’t ask that there.” The participant went on to remark that when discussions did occur, participants valued them; however, in some cases, reminders from the provider were insufficient, given the barriers. For example, 12 of 16 attending participants said that their postpartum provider told them to follow up with primary care, but 5 had not yet done so because they could not find a childcare provider or did not have time in addition to the demands of childcare.

Participants also received advice and support from family as cues to action for postpartum behaviors, describing how family members counseled them on their diet, encouraged them to take walks or time for themselves (and watched children while they did), or reminded them to check their blood pressure. One attending participant with HDP and gestational diabetes explained, “Because she [participant’s mother] has high blood pressure and has been taking her own blood pressure for years, she knew . . . what was normal for me and what was not. . . . When I came home and I had a headache, she encouraged me to take it, and at that time it was high.”

Finally, 2 participants reported that outreach from Medicaid encouraged them to engage in healthy behaviors (exercise and scheduling primary care visits). For example, one participant explained how she started exercising after receiving a brochure from her Medicaid provider stating that her Medicaid covered exercise and childcare at the YMCA (Table 3).

Postpartum visit attendees and nonattendees received similar cues to action during pregnancy but described differences postpartum. First, attendees were more likely than nonattendees to report having a primary care provider outside of pregnancy (12 of 16 vs 0 of 12). Second, all attendees with hypertension described counseling on blood pressure management at the postpartum visit, which nonattendees did not receive.

### **Self-efficacy**

Self-efficacy is a person’s belief that they are capable of engaging in an action that will result in positive change. During pregnancy, 5 of 15 participants with a chronic condition expressed comfort and confidence in understanding and managing their condition. Similarly, multiparous participants who had an HDP diagnosis in a previous pregnancy described confidence in managing HDP in each of their recent pregnancies. Home glucose and blood pressure monitoring, paired with training on how to monitor them accurately and when to report results to a physician, gave participants a sense of control over their condition during pregnancy.

After delivery, 7 of 28 participants described how monitoring and understanding their blood sugar or blood pressure levels postpartum gave them confidence in managing their chronic conditions. An attending participant with HDP and gestational diabetes remarked, “Since I’m not consistent, and I’m not on high blood pressure medication, I just take it and watch myself and try to record, so when I go back to the doctor, I’ll let him see it.”

Participants who were already engaged in care for a chronic condition before pregnancy expressed confidence about managing their condition postpartum. In contrast, participants who had a pregnancy-induced condition or who did not understand their diagnosis did not express confidence in their ability to manage or follow up on their condition. Postpartum visit attendees and nonattendees did not vary in perceived self-efficacy for managing high-risk conditions.

### **Discussion**

We presented the narratives of 28 low-income postpartum women of color from a high-risk, safety-net hospital about their perceptions and understanding of their cardiometabolic risks during and after pregnancy. Applying the Health Behavior Model, we described successful pathways through which participants engaged in prevention and management behaviors. We also noted multiple opportunities to address barriers, improve cues to action, and facilitate optimal postpartum health for patients with cardiometabolic conditions. Beyond gaps in knowledge and clinical support postpartum, our findings demonstrate how structural barriers (child-

care, insurance, transportation) must be addressed to improve postpartum and long-term health for people giving birth who have high-risk cardiometabolic complications.

Given the findings of our study and prior research (17–19), clinicians should expand and improve counseling related to cardiometabolic risk conditions during pregnancy, particularly around the need for future and ongoing surveillance and management. In our study, and prior studies, we found a disconnect between patient diagnoses and their own understanding of their pregnancy and future risk related to cardiometabolic disease (17–19,25). Consistent with prior research, participants in our study prioritized the needs of their developing fetuses and babies over their own health (17,26). Effective postpartum counseling may include value-based discussions helping mothers see heart disease prevention as part of caring for their family (27). Counseling that connects weight management, exercise, and diet to heart disease prevention may help motivate some people. In our study, only one participant explicitly connected her weight management goals to managing her hypertension. Our findings, however, showed that even when motivated, some participants were unable to overcome structural barriers to engage in healthy postpartum behaviors. Thus, innovative strategies are necessary to improve postpartum follow-up for patients with cardiometabolic complications of pregnancy in low-income populations. Strategies might include telehealth, home visiting, or specialty postpartum transition clinics following high-risk pregnancies (28). Clinics could also implement warm handoffs, in which a care coordinator assists the patient in identifying and contacting a provider to make an appointment for needed care (29).

The results of this study should be interpreted in light of its limitations. First, because of the diversity of diagnoses in our sample (by design), our guide did not probe all potential management behaviors for each diagnosis and asked open-ended questions (eg, we asked, what have you been doing to take care of yourself, rather than, do you take blood pressure medication). Thus, we are only able to base our analysis on information from the targeted questions asked during the interview, paired with information abstracted from the medical record. Second, the sample of 28 participants represents only 30% of potentially eligible patients. The low participation rate might reflect that the postpartum period is a busy time for most, or it might have been related to lingering effects of the COVID-19 pandemic. Finally, we did not systematically ask about postpartum care experiences in previous pregnancies, which might guide a person's approach to condition management.

Improving understanding of the link between cardiometabolic complications of pregnancy and future heart disease risk can empower pregnant and postpartum women to better manage their

own health. Study participants were interested in weight loss and disease management, but they received little guidance from their clinical care team, even when they attended the postpartum visit. Health systems must implement innovative strategies to support postpartum women, particularly those at high risk of severe maternal morbidity and future heart disease. In this low-income, Medicaid-insured population, few participants were engaged in care before pregnancy, and the postpartum period represents a unique opportunity to engage them in prevention and disease management (29). However, because of the many structural barriers noted, education or written referrals alone are insufficient. Successful strategies should both build on existing values, such as the desire to stay healthy for their family and address the demands of childcare and finances postpartum.

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## Author Information

Corresponding Author: Kaitlyn K. Stanhope, PhD, MPH, Department of Gynecology and Obstetrics, Emory University School of Medicine, 49 Jesse Hill Dr SE, Atlanta, GA 30303. Telephone: (404) 556-0169. Email: Kaitlyn.keirseystanhope@emory.edu.

Author Affiliations: <sup>1</sup>Emory University School of Medicine, Atlanta, Georgia. <sup>2</sup>Emory University Rollins School of Public Health, Atlanta, Georgia.

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## Tables

**Table 1. Key Domains of the In-Depth Interview Guide With Selected Questions Related to Understanding and Managing Cardiometabolic Risk Conditions, Atlanta, Georgia, 2021**

Domains	Selected questions
<b>Prenatal</b>	
Pregnancy discovery	Tell me about when you found out you were pregnant.
Prenatal care	What were your interactions with providers like during prenatal care visits? What concerns did you have about your own health during pregnancy? How did the provider address those concerns?
Expectations for postpartum care	What did your provider tell you about follow-up care for your diagnosis?
Understanding and managing cardiometabolic risk conditions	What was it like to be pregnant with high blood pressure? Where else did you get information about high blood pressure? What did your provider tell you about high blood pressure?
<b>Delivery</b>	
Delivery hospitalization	What instructions did the doctor or nurse give you about follow-up care for yourself?
Discharge	Did you have a visit for postpartum care or any other follow-up visit scheduled at the time you were discharged?
<b>Postpartum</b>	
Adjustment	Tell me how things went for you during the first few weeks after delivery. For many women, the first few weeks after delivery are an adjustment. What are some of the things you had to adjust to following this delivery?
Self-care: unmet needs	Is there anything that makes it challenging to take care of your own health?
Postpartum visit (barriers and facilitators or reasons for nonattendance)	What helps you take care of your own health?
Ideal care	What recommendations or advice did the provider give you about taking care of your own health?

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**Table 2. Characteristics of 28 Participants Who Completed Interviews for Cardiometabolic Risk Perceptions, Strengths, and Opportunities During Pregnancy and Postpartum Study, Atlanta, Georgia, 2021**

Characteristics <sup>a</sup>	Value <sup>b</sup>
<b>Health insurance</b>	
Medicaid	26 (93)
Uninsured	2 (7)
<b>Cardiometabolic risk condition</b>	
Diabetes	2 (7)
Gestational diabetes	6 (21)
Hypertension, pre-existing	15 (54)
<b>Hypertensive disorders of pregnancy</b>	
Gestational hypertension	12 (43)
Preeclampsia	13 (46)
<b>Race and ethnicity</b>	
Hispanic	7 (2)
Non-Hispanic Asian	7 (2)
Non-Hispanic Black	24 (86)
<b>Attended 4–12-week postpartum visit</b>	16 (57)
<b>Reported having a primary care physician</b>	43 (12)
<b>Median (25th–75th percentile)</b>	
<b>Age, y</b>	27 (23.5–33.0)
<b>Parity</b>	2 (1–4)
<b>Gestational age at entry into care, week</b>	12 (10–21)

<sup>a</sup> Categories can overlap (ie, a participant may have a chronic diabetes and a gestational hypertension diagnosis).

<sup>b</sup> All values are number (percentage) unless otherwise indicated.

**Table 3. Key Themes and Quotes From 28 Participants Who Completed Interviews by Using Elements of the Health Belief Model and Perinatal Status, Atlanta, Georgia, 2021**

Prenatal		Postpartum	
Subthemes	Postpartum quote	Subthemes	Postpartum quote
<b>Susceptibility</b>			
Few or no perceptible symptoms (for all hypertensive disorders and gestational diabetes)	<b>Attending participant<sup>a</sup> with gestational hypertension and preeclampsia</b> All my vitals were always so stable. They just sent me the cuff in the mail just, just because, um, they wanted me to watch myself. But, no, it was not, . . . There wasn't really any discussion. Um, all of the . . . going through prenatal, nothing was out the normal for my pregnancy. I didn't have anything abnormal.	<ul style="list-style-type: none"> <li>• Belief that pregnancy-related conditions would just go away and were not of concern following pregnancy</li> <li>• Perception that chronic hypertension (as diagnosed in the medical record) was only of concern during pregnancy (when it was detected with each pregnancy), likely because of limited engagement with care outside of pregnancy</li> </ul>	<b>Nonattending participant<sup>b</sup> with gestational hypertension</b> I wasn't really concerned about my blood pressure as much as probably other people may have been. I know it's something that runs in my family, but it has never been a problem that I had. There's more of something that seems to be just gestational.
<b>Severity</b>			
<ul style="list-style-type: none"> <li>• Primary concerns: impact of high-risk condition on the developing fetus (stillbirth, miscarriage, preterm birth, macrosomia, low birth weight)</li> <li>• Limited concerns: stroke or maternal death (during delivery) because of hypertension</li> </ul>	<b>Attending participant<sup>a</sup> with gestational hypertension</b> Interviewer: And with, with having preeclampsia, any time during your pregnancy, were you ever worried about your health or your baby's health? Response: Yes, I did...Like would he have it? Would he be . . . Would he have high blood pressure? Like, would I have my baby too, too, too early? Because my mom, see, my mom had . . . [pre-eclampsia], my momma had me early. She had me about when she was about [6 months or 7] months.	<ul style="list-style-type: none"> <li>• Potential stroke or death because of hypertension (the silent killer) and heart disease</li> <li>• Experiences with family, history of hypertension, and heart disease</li> </ul>	<b>Attending participant<sup>a</sup> with preeclampsia</b> When I went to my visits they was like, "Oh, your blood pressure's up. You don't feel sick?" And it really put my perspective in like I say of how serious it was because I . . . know how serious it was, but to actually go through it with yourself and knowing these are dangers when someone's actually telling you, this is how serious it is in your pregnancy. You could be walking around fine . . . what they say, they call blood pressure, the silent killer, and your blood pressure be sky high and you could just pass away."
<b>Benefits</b>			
<ul style="list-style-type: none"> <li>• Primary: preventing potential adverse consequences for baby</li> <li>• Limited: maintaining one's own health</li> </ul>	<b>Participant with chronic hypertension and superimposed preeclampsia<sup>c</sup></b> Interviewer: Do you feel like being pregnant made it easier to stop smoking or harder? Why? Response: Yeah, it was easier. Because I know why I had to. I had a, why . . . that [stopping smoking] was a challenge at first, but I was told that before I even got pregnant, so I wasn't surprised by that.	<ul style="list-style-type: none"> <li>• Primary: seeing one's kids grow up or staying healthy to care for family</li> <li>• Limited: heart disease prevention (1 participant only)</li> </ul>	<b>Participant with gestational hypertension</b> Now I still take my iron pills and like every now and then I take an aspirin just like you know, to be on the safe side 'cause I'm like, now I have 4 kids I have to watch over and I have to take care of myself.
<b>Barriers</b>			
<ul style="list-style-type: none"> <li>• Medication side effects</li> <li>• Challenges remembering to take medication</li> <li>• Cost of blood pressure monitor</li> <li>• Time, particularly if working or caring for older children</li> </ul>	<b>Attending participant<sup>a</sup> with chronic hypertension and superimposed preeclampsia<sup>c</sup></b> Yeah, I understand where they were trying to go. I got it because I was high risk, so I definitely needed to rest. [inaudible] but I have 2 other kids. I couldn't rest as much. Blood pressure medicine, no. I was taking . . . my last time taking blood pressure . . . they keep trying to prescribe it to me, but it makes me sick. I just can't, it makes me so sick.	<ul style="list-style-type: none"> <li>• Time and energy to focus on own health while caring for infant and older children</li> <li>• Cost or availability of blood pressure monitor</li> <li>• Finding a primary care physician who will take uninsured or Medicaid-insured patients</li> <li>• Food as a source of comfort</li> </ul>	<p><b>Nonattending participant<sup>b</sup> with preeclampsia</b> I'm just now really getting to myself to be honest with you. . . It happened subtly and just unconsciously. I was just so focused on my kids, and the newborn requires so much intricate care. And I was just so . . . I threw myself into accomplishing that I think that it, like slowly things would slip. Like, oh, I didn't shower today. You know? And I don't realize that till 8 o'clock at night, [laughs] at night. You know?</p> <p><b>Attending participant<sup>a</sup> with preeclampsia</b> The last time I called, which was about a month and a half ago, they didn't have nothing available. I'm trying to be a new patient. I'm really trying to get in, but it's hard.</p>

<sup>a</sup> Attending participant: attended a postpartum visit within the Grady Health System after her recent pregnancy.

<sup>b</sup> Nonattending participant: did not attend a postpartum visit within the Grady Health System after her recent pregnancy.

<sup>c</sup> Superimposed preeclampsia: Preeclampsia that develops in a patient with existing hypertension.

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(continued)

**Table 3. Key Themes and Quotes From 28 Participants Who Completed Interviews by Using Elements of the Health Belief Model and Perinatal Status, Atlanta, Georgia, 2021**

Prenatal		Postpartum	
Subthemes	Postpartum quote	Subthemes	Postpartum quote
<b>Cues to Action</b>			
<ul style="list-style-type: none"> <li>• Structured diabetes care curriculum</li> <li>• Worksheets for glucose monitoring and structured counseling</li> <li>• Telephone calls for blood pressure checks</li> <li>• Alarms, pill organizers</li> </ul>	<p><b>Attending participant<sup>a</sup> with chronic hypertension, superimposed preeclampsia<sup>c</sup>, and gestational diabetes</b></p> <p>Mainly what I did for myself was to try to set an alarm so that we know it's time to check your blood pressure, in the mornings make sure . . . And I had went and bought a pill organizer so I can keep my medicine by my bed and wake up and have the medicines right there. So, I wouldn't have to look for them. . . I liked the educational process, to know what to eat and not to eat because, like I said, that was the first time anybody told me when I got pregnant what I should not eat and what I needed to slow down eating because I didn't know.</p>	<ul style="list-style-type: none"> <li>• Home blood pressure check</li> <li>• Postpartum visit (limited)</li> <li>• Family advice and support (eg, through babysitting)</li> <li>• Insurance brochures</li> </ul>	<p><b>Attending participant<sup>a</sup> with chronic hypertension with superimposed preeclampsia<sup>c</sup></b></p> <p>They suggested that I see a primary doctor about my blood pressure. Oh, not my blood pressure, but since I had gestational hypertension. . . [W]e go to the YMCA, and the Y, it accepts the Medicaid that we have so it be somebody there watching the children while we go exercising. . . so like WellCare and another Medicaid, it pay for it for us. They pay for our exercising; they pay for people to watch the children while we go exercising. [Wellcare] be handing out brochures, but I never tried it out until like we went the other day.</p> <p><b>Participant with chronic hypertension</b></p> <p>Instead of just saying, Okay, I'm going to take a smoke. Go and take a walk instead. So, I've been hearing her in the back of my mind, "Come on, Ms. [last name]. You can do it. It's been working out really well though."</p>
<b>Self-Efficacy</b>			
<ul style="list-style-type: none"> <li>• Home blood pressure and glucose monitoring</li> <li>• Higher among participants with known chronic conditions</li> <li>• Existing relationships with primary care</li> </ul>	<p><b>Attending participant<sup>a</sup> with chronic hypertension</b></p> <p>My numbers were always great. They were never high. The only one time it did get high, I was actually in labor and didn't know. And that's the day that I went to the hospital. But, other than that, my numbers always stayed low.</p>	<ul style="list-style-type: none"> <li>• Understanding warning signs</li> </ul> <p>Home blood pressure monitoring, including at retail outlets with blood pressure cuffs</p>	<p><b>Attending participant<sup>a</sup> with gestational diabetes and gestational hypertension</b></p> <p>My sugar may be regular. Sometimes it'd be either, or every now and then, it'd be both. Since I'm not consistent, and I'm not on no high blood pressure medication, I just take it and watch myself and try to record, so when I go back to the doctor, I'll let him see it.</p> <p>Interviewer: Taking it [medication] at home, how did that make you feel?</p> <p>Participant: Like I was trying to help take care of myself. I knew how disastrous high blood pressure could be if it went too high, what could happen to me.</p>

<sup>a</sup> Attending participant: attended a postpartum visit within the Grady Health System after her recent pregnancy.

<sup>b</sup> Nonattending participant: did not attend a postpartum visit within the Grady Health System after her recent pregnancy.

<sup>c</sup> Superimposed preeclampsia: Preeclampsia that develops in a patient with existing hypertension.

## TOOLS FOR PUBLIC HEALTH PRACTICE

# A Dynamic Visualization Tool of Local Trends in Heart Disease and Stroke Mortality in the United States

Phong Le, MPH<sup>1</sup>; Michele Casper, PhD<sup>1</sup>; Adam S. Vaughan, PhD, MPH, MS<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

Cardiovascular disease (CVD) death rates have decreased in recent decades. However, in the last decade CVD death rates in many counties increased. Dissemination of local CVD trend data is critical to address increasing mortality.

**What is added by this report?**

This report introduces the Local Trends in Heart Disease and Stroke Mortality Dashboard, an online, interactive visualization of county-level death rates and trends for several CVD outcomes across stratifications of age, race and ethnicity, and sex.

**What are the implications for public health practice?**

This dashboard makes it easy for public health practitioners, health care providers, and community leaders to identify and address local health inequities in CVD mortality trends.

## Abstract

Efforts in the US to prevent and treat cardiovascular disease (CVD) contributed to large decreases in death rates for decades; however, in the last decade, progress has stalled, and in many counties, CVD death rates have increased. Because of these increases, there is heightened urgency to disseminate high-quality data on the temporal trends in CVD mortality. The Local Trends in Heart Disease and Stroke Mortality Dashboard is an online, interactive visualization of US county-level death rates and trends for several CVD outcomes across stratifications of age, race and ethnicity, and sex. This powerful visualization tool generates national maps of death rates and trends, state maps of death rates and

trends, county-level line plots of annual death rates, and bar charts of percentage changes. County-level death rates and trends were estimated by applying a Bayesian spatiotemporal model to data obtained from the National Vital Statistics System of the National Center for Health Statistics and US Census bridged-race intercensal estimates for the years 1999 through 2019. The Local Trends in Heart Disease and Stroke Mortality Dashboard makes it easy for public health practitioners, health care providers, and community leaders to monitor county-level spatiotemporal trends in CVD mortality by age group, race and ethnicity, and sex and provides key information for identifying and addressing local health inequities in CVD mortality trends.

## The Importance of Documenting Local Trends in CVD Mortality

Declines in cardiovascular disease (CVD) mortality in the US have been recognized as 1 of the 10 great public health achievements of the 20th century (1). These declines represent decades of successful efforts to improve CVD prevention and treatment, including decreases in smoking, increases in blood pressure control, and medical advances in early detection and treatment (2). However, these declines were not equally shared across geography and demographic groups (3). Counties in the southern US and Black adults across the US experienced less favorable trends, contributing to the marked geographic and racial disparities observed today (3–5).

CVD death rates have recently plateaued or begun to increase. National declines have stagnated in the last decade. For many counties in states across the US, CVD death rates, including those from heart disease and stroke, have increased (6–8). Unlike the highest CVD death rates, which are concentrated in the southern US, increases in CVD death rates are widespread and occur in counties in almost all US states (7–9). Additionally, these increases are more prevalent among adults aged 35 to 64 years than among adults aged 65 years or older, and are observed across race, ethnicity, and sex.



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Because of these trends and the marked geographic and demographic variation, the dissemination of high-quality local data on the temporal trends in CVD mortality assume heightened urgency. Public health practitioners, clinicians, and community leaders can use these data to inform policy and program decisions (10). For example, local data could be instrumental in prioritizing prevention efforts among demographic groups in places with increasing CVD death rates. Likewise, local CVD mortality data could reveal racial, ethnic, and geographic disparities masked by national data. To make county-level CVD death rates and trends more readily available and easily visualized, we created the Local Trends in Heart Disease and Stroke Dashboard (<https://www.cdc.gov/dhds/maps/hd-stroke-mortality-dashboard.htm>). The dashboard is an online, interactive visualization of death rates and trends for several CVD outcomes by age group, racial and ethnic group, and sex.

## Spatiotemporal Models of CVD Death Rates and Trends

The Local Trends in Heart Disease and Stroke Mortality Dashboard reports death rates and trends for 4 types of CVD: heart disease, coronary heart disease (CHD), heart failure, and stroke. We obtained county-level data for all deaths for the years 1999–2019 from the National Vital Statistics System of the National Center for Health Statistics. This period corresponds to the implementation of the *International Classification of Diseases, Tenth Revision* (ICD-10) (11). We used US Census bridged-race intercensal estimates for population data. Cause of death was defined according to the underlying cause of death listed on the death certificate and classified according to the following ICD-10 codes: CVD, I00–I99; heart disease, I00–I09, I11, I13, and I20–I51; CHD, I20–I25; and stroke, I60–I69. Death attributable to heart failure was defined as deaths for which any listed cause of death included “heart failure” (ICD-10 code I50) and “heart disease” (as defined above) was the underlying cause of death.

We used a Bayesian spatiotemporal model to estimate county-level CVD death rates by age group (ages 35–64 and  $\geq 65$  years), race and ethnicity (non-Hispanic American Indian/Alaska Native, non-Hispanic Asian/Pacific Islander, non-Hispanic Black, Hispanic, and non-Hispanic White), and sex (male and female) (12,13). Briefly, by accounting for correlation across space, time, and demographic groups, Bayesian spatiotemporal models can generate precise, reliable rates, even in the presence of small case counts and small populations. We fit these models with a Markov chain Monte Carlo algorithm. All death rates were age-standardized to the 2010 US population by using 10-year age groups.

These models have been used extensively to document spatiotemporal trends in CVD mortality, including deaths due to stroke, heart disease, and heart failure (3–5,7–9,13–16).

To quantify the temporal trends, we estimated total percentage change in death rates by using log-linear regression that included all years within each interval. Using relative change instead of absolute change allowed the comparison of results across outcomes and demographic groups. These comparisons would not be possible if absolute change were used because of large variation in death rates across outcomes and demographic groups. Our use of log-linear regression also permitted all rates to inform estimates of percentage change, which is not the case when calculating percentage change by using simple differences in rates between the beginning and end of each period.

To ensure that we reported precise rates only in sufficiently large populations, data for a demographic group within a county were suppressed if that group’s population in the given county in 2019 was fewer than 500 people and the death rates for all years were not reliable (ie, the width of the credible interval was smaller than the point estimate). This definition for suppression has been used extensively in studies that report county-level CVD mortality (5,8,9,14–16). Using this definition, different counties were suppressed by age, race and ethnicity, and sex for each outcome. However, within each demographic group, the same counties were suppressed for each outcome across all years.

We performed all statistical modeling in R (R Foundation for Statistical Computing) and used user-developed code. Additional details about the statistical analysis for these models are available in the dashboard.

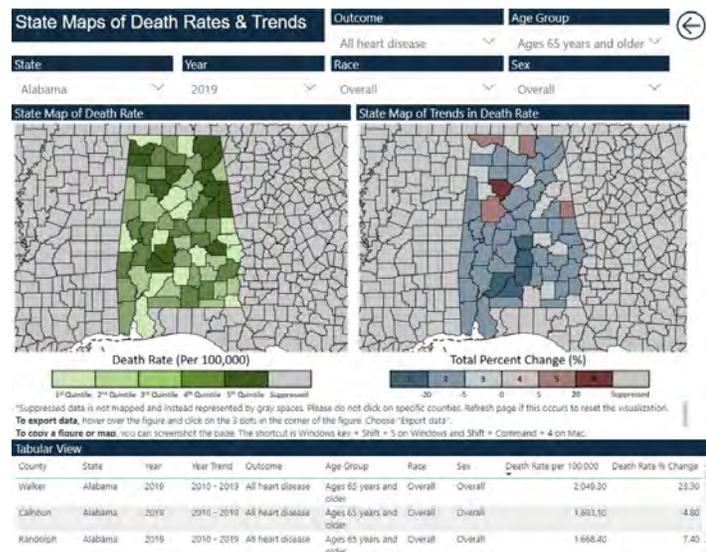
## Efficient Storage of Death Rate and Trend Data

The task of visualizing CVD death rates and trends across distinct spatial, temporal, and demographic strata required more than 75 million data points and demonstrated a need to efficiently store data. Increased efficiency in storage allowed the dashboard to speedily query data and to optimize load times. Data were stored in a relational database by using the second normal form (2NF) (17). Every combination of age, race and ethnicity, and sex had a distinct line of data that allowed for parameter-based query. The use of 2NF allowed for data points with repeated values to be stored separately and called only when needed. For example, each US county has an associated Federal Information Processing Standard (FIPS) code. When the FIPS code is selected, the associated county, state, and geographic data (ie, data that remain constant) can be saved in a separate table instead of repeating these

data points with the varying rate and trend data. As a result, the storage required for the 75 million data points in the database decreased from more than 5 gigabytes to fewer than 0.5 gigabytes (90% improved efficiency).

## Key Visualizations and Features

The Local Trends in Heart Disease and Stroke Mortality Dashboard is an intuitive, self-guided, online dashboard that provides high-quality data on trends in local CVD mortality to public health practitioners, clinicians, and community leaders for use in informing policy and program decisions. When first visiting the dashboard, users are shown a curated landing page that briefly describes the dashboard and allows for navigation to views at the national, state, and county levels. This navigation was designed to allow users to immediately select the geographic level of interest. Each view has interactive visualizations that automatically update according to the combination of user selections that stratify by geography, period, disease outcome, age group, race and ethnicity, and sex (Figure 1). Each view also includes a table that allows users to examine line listings of the displayed data.



**Figure 1.** Maps showing the full interface of the Local Trends in Heart Disease and Stroke Mortality Dashboard.

The national and state views include maps of county-level death rates and trends (Figure 2A and Figure 2B). Maps of death rates provide monochromatic visualization of county-level death rates for a selected year (1999 through 2019). Trend maps use a divergent color scheme to visualize county-level trends in death rates

for either the decade of 1999–2010 or 2010–2019. All maps allow users to hover over counties to see county-specific death rates and trends. National maps of death rates and trends are displayed separately, while state maps allow for a side-by-side comparison of death rates and trends.



**Figure 2.** Example of visualizations of death rates for all heart disease by county among population aged  $\geq 65$  years, all races and ethnicities, and both sexes in the Local Trends in Heart Disease and Stroke Mortality Dashboard. A, National map of death rates, 2019. B, National map of trends in death rates, 2010–2019. C, Annual death rates in Alpena County, Michigan, 1999–2019. D, Trends in death rates in Alpena County, Michigan, 1999–2010 and 2010–2019.

The county-level view includes line graphs of annual death rates and bar charts of percentage change for the period 1999–2019 (Figure 2C and Figure 2D). Unlike the national and state views, county-level views display a single county’s data for all years. The line plots enable the user to see annual changes and overall temporal trajectory of death rates in each county. The bar charts offer a summary of the magnitude of percentage change for 2 periods (1999–2010 and 2010–2019).

## Usability Design and Feedback

This dashboard was designed by using the PowerBI platform (Microsoft Corp). PowerBI provides a point-and-click solution for dashboard creation, which allows for development by all programming skill levels. Furthermore, PowerBI contains many features that increase its accessibility to users as defined by Section 508 of the Rehabilitation Act of 1973 (18), including built-in keyboard shortcuts, approved color schemes, and the ability to specify alternative text.

Key partners in the National Center for Chronic Disease Prevention and Health Promotion at the Centers for Disease Control and Prevention were invited to provide feedback on the dashboard’s ability to convey intuitive visualizations, layout preferences, and

accessibility. The feedback formed the basis for the implementation of key decisions for the dashboard, such as the decision to arrange views by geographic scope (national, state, county). Views were optimized so that users could use the visualizations in a way that best suited them. For example, users primarily interested in data at a national level requested that the national maps include Hawaii and Alaska to represent a complete national view. Users primarily interested in data at the state level preferred the side-by-side view to directly compare the geographic patterns of CVD death rates and trends.

## Examples of How the Dashboard Can be Used

The Local Trends in Heart Disease and Stroke Mortality Dashboard can benefit public health and community organizations addressing CVD mortality in numerous ways. The county-level visualizations enable users to identify counties with high or increasing mortality and tailor CVD prevention and treatment programs and policies to the needs of those communities (10,19,20). Given the spatiotemporal nature of the dashboard, areas that may benefit from efforts to improve cardiovascular health may be defined according to worsening temporal trends in CVD mortality rather than on high death rates alone. Additionally, data from the dashboard may be downloaded, allowing users to combine county-level CVD mortality trend data with county-level measures of local social, structural, and economic factors, to better understand the context for the observed trends (10,20). Furthermore, the ability to stratify trend data by demographic variables, such as race and ethnicity and sex, and to download all data and figures allows organizations to tailor CVD prevention programs and policies to the needs of key demographic groups in specific locations. Finally, the CVD surveillance data in this dashboard may be updated to include additional years of data or to reflect other notable county-level data.

## Summary

In light of widespread county-level increases in CVD death rates, there is a heightened urgency to make high-quality local-level trend data and maps easily available to public health practitioners, health care providers, and community leaders. The Local Trends in Heart Disease and Stroke Mortality Dashboard is an online interactive data visualization tool that makes it easy to monitor county-level spatiotemporal trends in CVD mortality by age group, racial and ethnic group, and sex. Using these data, the dashboard can provide key information for identifying and addressing local-level health inequities in CVD mortality trends.

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## Author Information

Corresponding Author: Adam S. Vaughan, PhD, MPH, MS, Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy, Atlanta, GA 30341. Telephone: 770-488-8060. Email: [avaughan@cdc.gov](mailto:avaughan@cdc.gov).

Author Affiliations: <sup>1</sup>Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, Atlanta, Georgia.

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## PROGRAM EVALUATION BRIEF

# Rapid Evaluations of Telehealth Strategies to Address Hypertension: A Mixed-Methods Exploration at Two US Health Systems During the COVID-19 Pandemic

Meera Sreedhara, PhD, MPH<sup>1</sup>; Kara Suvada, MPH<sup>1,2,3</sup>; Myles Bostic, MPH<sup>1,2</sup>;  
Amber Scott, MPH<sup>1,2</sup>; Ethan Blum, MS<sup>1</sup>; Julia Jordan, MPH<sup>1</sup>; Kincaid Lowe Beasley, MPH<sup>1</sup>

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## PEER REVIEWED

**Summary****What is already known on this topic?**

Telehealth is a promising intervention for blood pressure control and management. The COVID-19 pandemic accelerated health care systems' implementation and use of telehealth for continuity of care.

**What is added by this report?**

Rapid evaluations documented telehealth use among patients diagnosed with hypertension in 2 US health care systems during the COVID-19 pandemic. Telehealth offered consistent health care access and opportunities to monitor blood pressure outcomes for some patients. Health inequities may be exacerbated among patients with barriers to telehealth and blood pressure measurement.

**What are the implications for public health practice?**

Telehealth provides opportunities for blood pressure control and management, but the role of telehealth on equitable patient access to health care requires further evaluation.

## Abstract

Telehealth is a promising intervention for hypertension management and control and was rapidly adopted by health systems to ensure continuity of care during the COVID-19 pandemic. Rapid evaluations of telehealth strategies at 2 US health systems explored how telehealth affected health care access and blood pres-

sure outcomes among populations disproportionately affected by hypertension. Both health systems implemented telehealth strategies to maintain continuity of health care services during the COVID-19 pandemic. The evaluations used a mixed-method approach; qualitative interviews were conducted with key staff, and quantitative analyses were performed on patient electronic health record data. Both health systems exhibited similar trends in telehealth use, which allowed for continued access to health care for some patients but hindered other patients who had limited access to the internet or the equipment needed. Telehealth provides opportunities for blood pressure control and management. Further evaluation is needed to understand the role of broadband internet access as a social determinant of health and its impact on equitable patient access to health care.

## Introduction

More than half of US adults who have hypertension have uncontrolled high blood pressure, which increases the risk of cardiovascular disease and stroke (1). Disparities in hypertension and blood pressure control persist, in part, because of structural and systemic inequities (2). The effect of the COVID-19 pandemic on hypertension control is unclear because only a small amount of evidence exists, which is conflicting and did not evaluate the impact among populations at highest risk for hypertension (3–5).

Telehealth, the use of electronic and telecommunication technologies for health care delivery and education, is recommended for blood pressure control (6). Although the COVID-19 pandemic limited the delivery of office-based primary care visits and blood pressure assessments (7), less stringent federal and state regulations led to the broad expansion of telehealth, including primary care (7,8).



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Studies conducted during the COVID-19 pandemic reported changes in telehealth use and subsequent inequities in the general population (8–10). Limited research described the use of telehealth for hypertension control in a primary care setting (3,5). As of March 2022, 20.5% of US adults reported having had a recent telehealth appointment (9), with use during the pandemic varying by such factors as race, ethnicity, age, insurance status, income, language, and urbanicity (8,10). Despite the potential to improve access to health care for people lacking transportation or living in rural areas (11), it is unclear how telehealth has affected access to chronic disease management services during the pandemic (3,5). As national organizations call for the equitable expansion of telehealth (11), practice-based evidence describing the role of telehealth in supporting patients with a diagnosis of hypertension is needed for health care systems to successfully adapt to the shifting landscape of health care delivery.

## Purpose and Objectives

To quickly generate practice-based evidence, we conducted rapid evaluations of 2 US health care systems' use of telehealth strategies to address hypertension during the COVID-19 pandemic. This study reports on a subset of evaluation findings, which aimed to 1) examine telehealth use among patients with hypertension, with a focus on populations who experience barriers to care and 2) explore the effect of telehealth on blood pressure outcomes.

## Intervention Approach

We evaluated how 2 US health care systems (ARcare and Terros Health) provided telehealth services for patients with hypertension in a primary care setting during the COVID-19 pandemic. Both systems used team-based care and self-measured blood pressure monitoring approaches for hypertension management and control. Telehealth was delivered at both sites via telephone-only and videoconferencing modalities as part of comprehensive primary care and chronic disease management services.

ARcare is a federally qualified health center (FQHC) that comprises 48 clinics that serve 17 counties in Arkansas, Kentucky, and Mississippi. We derived data for this evaluation from ARcare's headquarters in Augusta, Arkansas. ARcare serves patients who are medically underserved, have low incomes, experience homelessness, and live in rural communities. Telehealth services began in 2018 and were scaled up in March 2020 because of the COVID-19 pandemic. Telehealth is primarily delivered clinic to clinic, where patients visit a clinic outfitted with technology to connect with an off-site health care provider, which allows for collection of data on vital signs and laboratory tests. Telehealth is also delivered at satellite clinics (eg, schools) or to patients at home.

Terros Health (hereinafter, Terros) serves a diverse population at 13 locations in Arizona, including 4 FQHCs. Patients experience health disparities caused by food insecurity, low income, and homelessness, and most patients are uninsured or receive Medicaid. Terros began providing telehealth in March 2020 because of the COVID-19 pandemic. Most patients engage in telehealth from their home. Health care providers can review blood pressure readings if patients have a blood pressure monitor.

## Methods

We conducted a systematic screening and evaluability assessment in 2020 to select health care systems to participate in rapid evaluations (12). Centers for Disease Control and Prevention institutional review board approval was not required for this evaluation project. This analysis reports findings from the mixed-methods outcome evaluation. We triangulated qualitative and quantitative findings to comprehensively describe telehealth strategies, reach to patients, and blood pressure outcomes.

### Qualitative data sources and analysis

We conducted semistructured interviews at each site in June 2021. Two interviewers and a notetaker attended each interview. Informed consent was obtained. A professional service transcribed recorded interviews verbatim.

We tailored interview guides by staff type and in alignment with the evaluation questions to understand the telehealth strategies, reach to patients, and perceived impact on health. We interviewed health system leaders, practice managers, telehealth implementation leaders, data analysts, financial analysts, and health care providers. We conducted 8 ARcare interviews with 12 participants and 8 Terros interviews with 9 participants.

We coded and analyzed transcripts in Dedoose version 9.0.46 (SocioCultural Research Consultants, LLC). Evaluation questions and constructs from the Consolidated Framework for Implementation Research (patient needs and resources, relative advantage, culture, implementation climate) guided codebook development (13). The codebook guided deductive coding of transcripts, and codes were added or revised inductively (14). To increase validity, all coders analyzed 1 transcript together. The remaining transcripts were independently coded and reconciled by 2 coders each, and they discussed disagreements until consensus was met. The following themes emerged during thematic analysis: telehealth use, community awareness of telehealth, patient barriers and facilitators to health care, telehealth as a barrier and facilitator to health care, and impact on blood pressure outcomes.

## Quantitative data sources and analysis

Each health care system exported de-identified data from their electronic health record and population health tools for before and after telehealth implementation due to COVID-19: March 1, 2019, through March 31, 2021, for ARcare, and March 1, 2019, through August 31, 2021, for Terros.

Data sets from ARcare and Terros had different variables and formats, but we used similar statistical methods. Study populations from both sites included patients with a diagnosis of hypertension, a primary care visit, and a blood pressure measurement during the observation period (ARcare,  $N = 574$ ; Terros,  $N = 986$ ). We calculated frequencies, percentages, and means (SDs) for patient demographic characteristics, patient clinical characteristics, and type of patient encounter (eg, telehealth, in-person). We defined blood pressure control as  $<140/90$  mm Hg. We calculated blood pressure control rates for patients in the study population (number of patients with controlled blood pressure divided by the total number of patients with hypertension) for each site during the observation periods before and after telehealth implementation due to COVID-19. We used  $\chi^2$  and Fisher exact tests to assess differences in patient encounter type across patients' race and ethnicity and blood pressure control rate across observation periods.

We analyzed data in SAS version 9.4 (SAS Institute Inc) and Stata version 17 (StataCorp LLC) and visualized data by using Excel 2019 (Microsoft Corp).

## Results

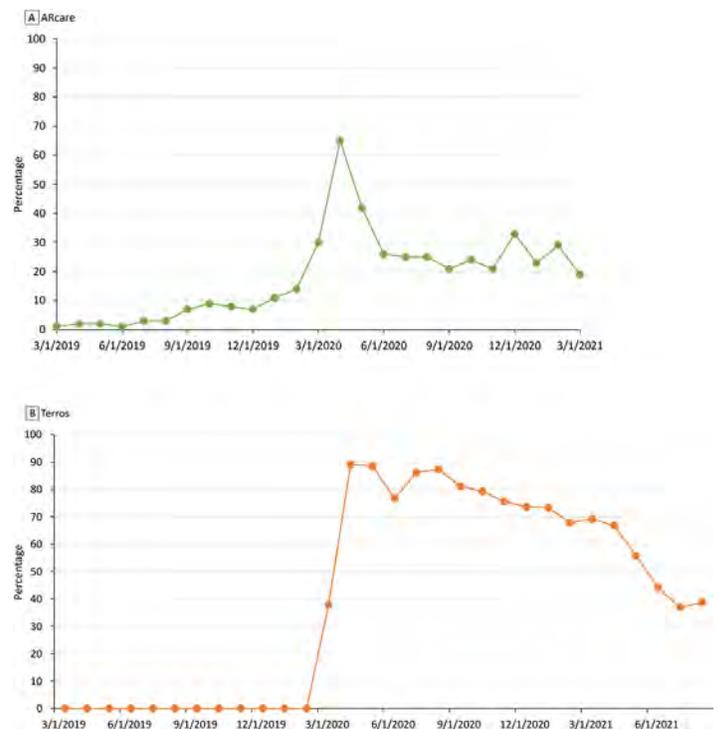
Of 574 patients at ARcare, 57.3% were female, 64.5% were White, 34.1% were Black, and 1.0% were Hispanic; 35.7% received Medicare (Table). Of 986 patients at Terros, 43.7% were female, 71.6% were White, 18.9% were Black or African American, and 21.5% were Hispanic.

## Reach to patients

### Use of telehealth

Both sites had similar trends in telehealth use, before and after the transition to telehealth caused by COVID-19 (Figure). The proportion of telehealth encounters at ARcare was small ( $<10\%$ ) before the pandemic, and Terros had not yet implemented telehealth. Use of telehealth peaked at 65% (348 telehealth encounters of 537 total encounters) in April 2020 at ARcare and almost 90% in April (342 telehealth encounters of 384 total encounters) and May 2020 (284 telehealth encounters of 321 encounters) at Terros. After April 2020, the proportion of telehealth encounters for ARcare declined through March 2021 to 19% (70 telehealth encounters of 371 total encounters) but remained higher than before the pandemic. Simil-

arly, for Terros, telehealth visits declined to 39% in August 2021 (119 telehealth encounters of 308 total encounters). The relationship between type of patient encounter and patients' race (Terros  $P < .001$ ) and race and ethnicity (ARcare  $P < .001$ ) was significant at both sites (Appendix Supplemental Table 1 and Table 2). Although the study population at ARcare included few Hispanic patients ( $n = 6$ ), Hispanic patients had the highest percentage of telehealth encounters (28%; 16 of 57) compared with other patients. Despite having small cell sizes for other patients, a high percentage of telehealth use was observed for White patients in Terros' study population during their most recent encounter (44%; 314 of 706). Staff at Terros qualitatively expressed that the telehealth adoption rate for "everybody else, [was] slow and very steady and it remained disparate."



**Figure.** Percentage of encounters that were telehealth encounters among patients with a diagnosis of hypertension in A) ARcare and B) Terros health care systems, 2019–2021.

ARcare and Terros staff members (5 ARcare interviews, 3 Terros interviews) indicated that convenience was perceived as a primary reason among patients for using telehealth and was often appreciated after an initial telehealth encounter. Both sites indicated that telehealth reduced appointment no-show rates, an idea that was conveyed by a health care provider at Terros who perceived that

“e-visits are kept more by patients . . . because our patient population faces some transportation barriers, so for them to be able to connect to the e-visit, it seems to have been easier for them.”

### **Community awareness of telehealth**

ARcare promoted community awareness of telehealth at satellite clinics via signs describing telehealth services and booths to disseminate information. Terros marketed telehealth services, informed patients about the convenience of same-day telehealth appointments, and staff, including community health workers, reached out to eligible patients, explained telehealth options, helped with connection issues, and worked with hesitant patients.

### **Patient barriers and facilitators to accessing health care**

Social determinants of health that adversely affect patients’ overall access to health care (eg, lack of income, homelessness, lack of health care providers, language barriers) were described nearly universally (7 ARcare interviews, 7 Terros interviews). Transportation was commonly identified as a barrier to using traditional in-person care, and telehealth was viewed as improving access to care for patients experiencing some of these upstream barriers.

### **Telehealth as a facilitator and barrier to accessing health care**

Each health system (4 ARcare interviews, 5 Terros interviews) offered insights into how telehealth facilitates access to care and can increase touchpoints within health systems. ARcare further noted the utility of telehealth for patients living in rural areas. Terros described the usefulness of telehealth for patients who cannot take time off work or lack childcare.

Conversely, both health systems described how telehealth can exacerbate a lack of health care access. Common patient barriers to engaging in telehealth were lack of access to equipment (eg, computer, smartphone, e-mail address, blood pressure monitor) and broadband internet. Other patients faced barriers because of limited data plans, poor internet connectivity, or gaps in technical knowledge and skills, which limited the information that could be gathered by health care providers and sometimes resulted in switching to telephone-only or an in-person visit.

### **Blood pressure outcomes**

For patients at ARcare, we found no significant differences in blood pressure control between baseline (53.4%, March 2019–February 2020) and after expansion of telehealth services (57.4%, March 2020–March 2021) ( $P = .31$ ).

At Terros, 85.7% of patient visits were missing data on a systolic blood pressure reading, which was corroborated during interviews. Staff indicated that few patients who engaged in telehealth had a blood pressure monitor, but these patients were perceived as “more adherent and consistent” because of telehealth.

## **Implications for Public Health**

These rapid evaluations explored how telehealth strategies delivered during the COVID-19 pandemic in a primary care setting affected use of telehealth, potential disparities in use by race and ethnicity, and blood pressure outcomes in 2 health care systems. Both systems had similar trends in telehealth use that align with the literature and federal reports (8–10). A review of telehealth studies conducted during the COVID-19 pandemic supports our finding of conflicting evidence on telehealth use and patient race and ethnicity (10). ARcare and Terros promoted community awareness of telehealth, and health systems could consider implementing and evaluating additional approaches that address upstream barriers to use.

ARcare’s blood pressure control rates did not decrease after telehealth implementation, which supports the adequacy of telehealth for primary care services. ARcare’s clinic-to-clinic telehealth approach of outfitting local clinics with technology might lessen patients’ technology and transportation barriers while allowing for consistent blood pressure measurement. A similar telehealth approach at Veterans Affairs hospitals demonstrated parity with in-person diabetes care (15). A nationally representative study of outpatient care in the US during the COVID-19 pandemic (7) helps explain why changes in blood pressure control could not be calculated for patients at Terros. The study found that blood pressure assessment was significantly less common among telemedicine encounters compared with in-person (7). Emerging evidence suggests the need for interventions that support consistent data collection during telehealth encounters.

Qualitative findings from ARcare and Terros suggest that telehealth offered consistent or improved health care for some patients with a diagnosis of hypertension during the COVID-19 pandemic but not for patients lacking technology or internet, suggesting that telehealth is not a universal solution and requires tailoring to some populations. Similar barriers to health care and engagement in telehealth have been reported (8,10,11). Relaxed regulations during the COVID-19 pandemic allowed health systems to deliver audio-only telehealth and improve opportunities for use among patients lacking technology or broadband internet (11). Long-term sustainability of these policy changes is uncertain, but

national authorities recommend extending flexibilities and prioritizing broadband internet as a social determinant of health (11). Policy levers may foster equitable access to health care services that support hypertension management and control.

This rapid evaluation has limitations. Findings are not generalizable to all US health care systems but may expand the evidence base. We were unable to interview patients, but staff reported patient barriers and facilitators to accessing health care and telehealth that align with published literature (10,11). Quantitative findings should be interpreted cautiously because study population sizes were small and were not adjusted for confounders or bias. We could not calculate blood pressure control for Terros, but this illuminated a barrier to improving the use of telehealth for hypertension management and control. Practice-based evidence generated by these rapid evaluations suggest that telehealth offers consistent health care access and blood pressure outcomes for some patients with hypertension, but health inequities may be exacerbated among patients with barriers to telehealth and blood pressure measurement.

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## Author Information

Corresponding Author: Meera Sreedhara, PhD, MPH, Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, 4770 Buford Hwy, Mailstop S107-3, Atlanta, GA 30341. Telephone: 404-498-4058. Email: qlq1@cdc.gov.

Author Affiliations: <sup>1</sup>Division for Heart Disease and Stroke Prevention, Centers for Disease Control and Prevention, Atlanta,

Georgia. <sup>2</sup>Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee. <sup>3</sup>Department of Epidemiology, Emory Rollins School of Public Health, Atlanta, Georgia.

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## Table

**Table. Characteristics of Patients With Hypertension at ARcare and Terros Health<sup>a</sup>**

Characteristic	ARcare (March 1, 2019–March 31, 2021) <sup>a</sup>	Terros Health (March 1, 2019–August 31, 2021) <sup>a</sup>
<b>Total no. of patients</b>	574 (100.0)	986 (100.0)
<b>Sex</b>		
Male	241 (42.0)	555 (56.3)
Female	329 (57.3)	431 (43.7)
Unknown	4 (0.7)	0
<b>Race</b>		
American Indian or Alaskan Native	0	14 (1.4)
Asian	1 (0.2)	16 (1.6)
Black or African American	196 (34.1)	186 (18.9)
Latino	— <sup>b</sup>	1 (0.1)
Native Hawaiian and Other Pacific Islander	1 (0.2)	7 (0.7)
White	370 (64.5)	706 (71.6)
More than 1 race reported	— <sup>b</sup>	4 (0.4)
Unknown or declined	6 (1.0)	52 (5.3)
<b>Ethnicity</b>		
Hispanic	6 (1.0)	212 (21.5)
Non-Hispanic	534 (93.0)	711 (72.1)
Unknown	34 (5.9)	63 (6.4)
<b>Insurance status</b>		
Medicaid	73 (12.7)	— <sup>b</sup>
Medicare	205 (35.7)	— <sup>b</sup>
Private	193 (33.6)	— <sup>b</sup>
Self-pay	93 (16.2)	— <sup>b</sup>
Other	10 (1.7)	— <sup>b</sup>
<b>Vitals at most recent visit, mean (SD)</b>		
Age, y	54.4 (13.6)	53.0 (12.1)
Systolic blood pressure, mm Hg	137.4 (19.3)	142.6 (20.5) <sup>c</sup>
Diastolic blood pressure, mm Hg	83.0 (11.1) <sup>d</sup>	70.9 (10.0) <sup>e</sup>
Pulse	— <sup>b</sup>	68.1 (28.5) <sup>f</sup>

<sup>a</sup> ARcare is a federally qualified health center (FQHC) that comprises 48 clinics that serve 17 counties in Arkansas, Kentucky, and Mississippi. Terros Health serves a diverse population at 13 locations in Arizona, including 4 FQHCs. Values are number (percentage) unless otherwise indicated.

<sup>b</sup> Data not collected.

<sup>c</sup> Data missing for 286 patients.

<sup>d</sup> Data missing for 2 patients.

<sup>e</sup> Data missing for 287 patients.

<sup>f</sup> Data missing for 313 patients.

## Appendix. Supplemental Tables

**Appendix. Supplemental Table 1. Telehealth Encounters Among 574 Patients, by Race and Ethnicity, ARcare, March 1, 2019–March 31, 2021**

Race and ethnicity	No. of encounters (% of encounters that were telehealth) <sup>a</sup>	P value <sup>b</sup>
Non-Hispanic White	1,152 (15.8)	<.001
Non-Hispanic Black	687 (18.8)	
Hispanic	16 (28.1)	
Other	15 (25.0)	

<sup>a</sup> Determined by  $\chi^2$  test and compares uptake of patient encounter across patients' race and ethnicity.

<sup>b</sup> Patients could have had  $\geq 1$  telehealth encounter.

**Appendix. Supplemental Table 2. Telehealth Use by Modality (Videoconferencing and Telephone-Only) and Overall Among 986 Patients, by Race and Ethnicity, Terros Health, March 1, 2019–August 31, 2021**

Characteristic	No. of videoconference visits (% of all visits)	No. of telephone-only visits (% of all visits)	Total no. of telehealth visits (% of all visits)	P value <sup>a</sup>
<b>Race</b>				
American Indian or Alaska Native	1 (7.1)	5 (35.7)	6 (42.8)	<.001
Asian	1 (6.3)	7 (43.8)	8 (50.1)	
Black	22 (11.8)	55 (29.6)	77 (41.4)	
Latino	1 (100)	0	1 (100)	
Native Hawaiian or Other Pacific Islander	0 (0)	2 (28.6)	2 (28.6)	
White	90 (12.8)	224 (31.7)	314 (44.5)	
More than 1 race	2 (50.0)	0	2 (50.0)	
Unreported	6 (11.5)	14 (26.9)	20 (38.4)	
<b>Ethnicity<sup>b</sup></b>				
Hispanic	18 (8.5)	77 (36.3)	95 (44.8)	.13
Not Hispanic	95 (13.4)	215 (30.2)	310 (43.6)	
Unknown	10 (15.9)	15 (23.8)	25 (39.7)	

<sup>a</sup> Determined by Fisher exact test because of small cell size; compares uptake of patient encounter (ie, videoconferencing, telephone-only, in-person) across patients' race and ethnicity, respectively. Data on in-person encounters are not presented.

<sup>b</sup> Total number of telehealth encounters differs between race and ethnicity because of missing information on ethnicity.

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