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Trends in Prevalence, Treatment, and Control of Cardiometabolic Risk Factors Among Adults With Hypertension in the United States, 1999-2023

Hyeok-Hee Lee, MD, PhD,[a,b] Emily B. Crawford, MD,[a,c] So Mi Jemma Cho, PhD,[d,e,f] Anna K. Krawisz, MD,[a,g] Stephen P. Juraschek, MD, PhD,[c] Jennifer L. Cluett, MD,[c] Hokyou Lee, MD, PhD,[b] Hyeon Chang Kim, MD, PhD,[b] Pradeep Natarajan, MD, MMSc,[d,e,h] Rishi K. Wadhera, MD, MPP, MPhil,[a,g,i] Eric A. Secemsky, MD, MSc[a,g]

ABSTRACT

BACKGROUND Hypertension-related deaths in the United States have sharply increased over the past decade. Understanding factors behind this concerning trend is crucial to guide public health strategies.

OBJECTIVES This study sought to examine changes in prevalence, treatment, and control of cardiometabolic risk factors among U.S. adults with hypertension.

METHODS Using National Health and Nutrition Examination Survey, we identified 21,822 adults with hypertension from 1999 to 2023. Trends in age-adjusted prevalence of diabetes, hyperlipidemia, obesity, smoking, and high-risk drinking, as well as in age-adjusted treatment and control rates for hypertension, diabetes, and hyperlipidemia, were assessed.

RESULTS In adults with hypertension, prevalence of diabetes increased from 17.2% (95% CI: 14.6%-20.2%) in 1999-2000 to 27.8% (95% CI: 25.2%-30.7%) in 2021-2023. Among patients with hypertension and diabetes, the proportion receiving treatment for both conditions rose until 2009-2010 but subsequently plateaued (71.6% in 2021-2023; 95% CI: 67.5%-75.4%). A similar trend was observed for the proportion achieving control of both conditions, which remained at 31.2% in 2021-2023 (95% CI: 26.5%-36.3%). Prevalence of hyperlipidemia decreased in adults with hypertension but was still high at 73.1% (95% CI: 70.6%-75.4%) in 2021-2023. Among patients with hypertension and hyperlipidemia, treatment and control rates for both conditions increased only until around 2007; the respective rates were 50.4% (95% CI: 47.2%-53.6%) and 32.3% (95% CI: 29.5%-35.2%) in 2021-2023. Prevalence of concurrent diabetes and hyperlipidemia in adults with hypertension nearly doubled from 12.5% (95% CI: 10.6%-14.7%) in 1999-2000 to 21.3% (95% CI: 19.0%-23.8%) in 2021-2023. Among patients with hypertension, diabetes, and hyperlipidemia, the treatment rate for all 3 conditions increased until 2007-2008 and plateaued afterward (62.1% in 2021-2023; 95% CI: 56.6%-67.2%). The control rate for all 3 conditions followed a similar trend but remained low at 26.3% (95% CI: 20.8%-32.6%) in 2021-2023. Prevalence of obesity and high-risk drinking increased over time, whereas prevalence of smoking held steady.

CONCLUSIONS The burden of cardiometabolic risk factors among U.S. adults with hypertension has increased overall, with concurrent diabetes and hyperlipidemia now affecting more than 1 in 5. Only one-quarter of adults with hypertension, diabetes, and hyperlipidemia have all 3 conditions controlled—a proportion that has not improved in more than a decade. (JACC. 2025;86:2577-2593) © 2025 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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From the [a]Richard A. and Susan F. Smith Center for Outcomes Research in Cardiology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, USA; [b]Department of Preventive Medicine, Yonsei University College of Medicine, Seoul, Korea; [c]Department of Medicine, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, USA; [d]Program in Medical and Population Genetics and the Cardiovascular Disease Initiative, Broad Institute of MIT and Harvard, Cambridge, Massachusetts, USA; [e]Cardiovascular Research Center and Center for Genomic Medicine, Massachusetts General Hospital, Boston, Massachusetts, USA; [f]Integrative Research Center for Cerebrovascular and Cardiovascular Diseases, Yonsei University College of Medicine, Seoul, Korea; [g]Division of Cardiovascular Medicine, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, USA; [h]Cardiology Division, Massachusetts General Hospital, Boston, Massachusetts, USA; and the [i]Department of Health Policy and Management, Harvard T.H. Chan School of Public Health, Boston, Massachusetts, USA.

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ABBREVIATIONS AND ACRONYMS

BP = blood pressure

DBP = diastolic blood pressure

GLP-1 = glucagon-like peptide-1

HbA1c = glycosylated hemoglobin

NCHS = National Center for Health Statistics

NHANES = National Health and Nutrition Examination Survey

SBP = systolic blood pressure

Hypertension, which affects >1.2 billion people worldwide,[1] is the leading cause of preventable morbidity and mortality.[2] In 2022, >130,000 individuals died from causes related to hypertension in the United States alone, a figure that has nearly doubled since 2012.[3,4] This sharp increase in hypertension-related mortality far exceeds the rise in hypertension prevalence, raising the possibility that the burden of cardiometabolic risk factors—such as diabetes, hyperlipidemia, and obesity—could have increased among patients with hypertension. Recent studies demonstrated that, in the general U.S. population, the age-standardized prevalence of diabetes increased from 9.8% in 1999-2000 to 14.3% in 2017-2018,[5] while that of obesity rose from 35.4% in 2011-2012 to 43.4% in 2017-2018.[6] However, how the prevalence of various cardiometabolic risk factors has changed among individuals with hypertension remains unclear.

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On the other hand, it is also possible that the treatment and control of comorbid cardiometabolic risk factors, along with hypertension itself, have worsened in adults with hypertension. Although prior reports have shown that blood pressure (BP) control to <140/90 mm Hg has hovered around 50% among U.S. adults with hypertension over the past decade,[7] evidence remains limited regarding the extent to which comorbid diabetes and hyperlipidemia have been managed in this population. Understanding these management patterns, alongside trends in the prevalence of cardiometabolic risk factors, may be essential for informing public health strategies to curb the rising burden of hypertension-related mortality in the United States.

Using the National Health and Nutrition Examination Survey (NHANES), we aimed to examine the temporal trends in prevalence, treatment, and control of cardiometabolic risk factors among adults with hypertension in the United States from 1999 to 2023.

METHODS

DATA SOURCE AND STUDY POPULATION. NHANES is a series of cross-sectional surveys conducted by the National Center for Health Statistics (NCHS) to monitor the health and nutritional status of the U.S. population. Participants are sampled using a complex, multistage design to ensure that all resulting estimates are representative of the civilian, noninstitutionalized U.S. population. The surveys are conducted in 2-year cycles via in-home interviews and medical examinations performed at mobile examination centers.

We identified all nonpregnant adults ≥20 years of age with hypertension within NHANES from the 1999-2000 through the August 2021-August 2023 cycles (N = 21,822) (Supplemental Figure 1). Hypertension was defined as systolic blood pressure (SBP) ≥140 mm Hg, diastolic blood pressure (DBP) ≥90 mm Hg, or the self-reported use of BP-lowering medication.[7] The 140/90 mm Hg threshold was used instead of 130/80 mm Hg because most of the study period (1999-2017) fell within the period when hypertension was defined as BP ≥140/90 mm Hg. The study protocols of NHANES were approved by the NCHS Ethics Review Board, and all participants provided written informed consent.

DATA COLLECTION. Participants self-reported their age, sex, race/ethnicity, family income-to-poverty ratio, and health insurance status. BP was measured after a 5-minute seated rest. From the 1999-2000 through the 2017-2018 cycles, up to 4 consecutive BP measurements were obtained 30 seconds apart by trained physicians using the auscultatory method. Beginning in the 2017-2018 cycle, 3 consecutive BP measurements were obtained 60 seconds apart by trained health technicians using the oscillometric method (Omron HEM-907XL; OMRON Healthcare). Both auscultatory and oscillometric methods were used during the 2017-2018 cycle.[8] We averaged all available BP measurements for each individual to define their BP. Oscillometric BP measurements were calibrated per the NCHS report by adding 1.5 mm Hg to SBP and subtracting 1.3 mm Hg from DBP to align them with auscultatory BP measurements.[9]

Height and weight were measured by trained health technicians; body mass index was calculated as weight in kilograms divided by height in meters squared. Smoking and drinking status were self-reported. Serum glycosylated hemoglobin (HbA1c) and total cholesterol levels were measured using

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liquid chromatography-based and enzymatic methods, respectively, from nonfasting blood samples.

CARDIOMETABOLIC RISK FACTORS AND THEIR TREATMENT AND CONTROL. We assessed 5 commonly recognized cardiometabolic risk factors with well-established health implications[10-12]; 1) diabetes, defined as HbA1c ≥6.5% or physician diagnosis of diabetes; 2) hyperlipidemia, defined as total cholesterol ≥200 mg/dL or physician diagnosis of high cholesterol[13]; 3) obesity, defined as body mass index ≥30 kg/m^2; 4) current smoking, defined as having smoked ≥100 cigarettes in a lifetime and currently smoking; and 5) high-risk drinking, defined as weekly alcohol intake >14 drinks for males and >7 drinks for females.[14] We excluded physical inactivity because of inconsistencies in the NHANES questionnaires across survey cycles.

Treatment of hypertension, diabetes, and hyperlipidemia was defined as the self-reported use of BP-, glucose-, and lipid-lowering medications, respectively. Hypertension control was defined as SBP <140 mm Hg and DBP <90 mm Hg. Diabetes control was defined as HbA1c <7%. Hyperlipidemia control was defined as total cholesterol <200 mg/dL.

STATISTICAL ANALYSIS. Analyses were conducted based on 2-year NHANES cycles from 1999-2000 through August 2021-August 2023; the 2019-March 2020 cycle was disrupted by the COVID-19 pandemic and therefore was combined with the 2017-2018 cycle, as recommended by the NCHS. We assessed baseline characteristics as well as the prevalence and number of cardiometabolic risk factors in participants with hypertension. Among individuals with hypertension and concurrent diabetes and/or hyperlipidemia, we calculated: 1) the proportion receiving treatment for all coexisting conditions; and 2) the proportion achieving control of all coexisting conditions, with the latter assessed in the overall population rather than restricted to treated individuals. All estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023), unless otherwise specified. The age categories used for standardization were 20 to 44 years (13.0%), 45 to 64 years (43.3%), and ≥65 years (43.7%); the 20 to 44 years and 45 to 64 years categories were merged in analyses involving participants with hypertension and concurrent diabetes and hyperlipidemia, as the 95% CIs of the estimates for the 20 to 44 years category could not be reliably estimated. Temporal trends were analyzed using Joinpoint regression,[15] treating each survey cycle's midpoint as the time point. The optimal number of breakpoints was selected using the weighted Bayesian information criterion method, while breakpoint locations were determined by grid search with local optimization. We prespecified the maximum number of breakpoints to 1, following the developer's recommendation for analyses with 11 data points.[16] *P* values for trend in each segment were calculated using the nonparametric Empirical Quantile method with 5,001 resamples.

In subgroup analyses, we stratified patients with hypertension and concurrent diabetes and hyperlipidemia by sex and race/ethnicity within each survey cycle. We also pooled the patients from the 2 most recent survey cycles (2017-March 2020 and August 2021-August 2023) and stratified them by age, sex, race/ethnicity, family income-to-poverty ratio, and health insurance status. In secondary analyses, we described class-specific use of BP-, glucose-, and lipid-lowering medications and the number of medication classes through the 2017-March 2020 cycle, using data from medication inventory questionnaires.

We conducted 5 sensitivity analyses. First, we used the BP threshold of 130/80 mm Hg to define hypertension and its control.[17] Second, we expanded the definitions of diabetes and hyperlipidemia to include self-reported medication use. Third, we truncated our trend analyses at the 2015-2016 cycle to mitigate the potential effects of the transition from auscultatory to oscillometric BP measurement in the 2017-2018 cycle. Fourth, we fitted natural spline models with 3 degrees of freedom as a separate trend analysis to avoid arbitrary specification of model parameters. Fifth, we reported a new measure of management—that is, a care cascade of diagnosis, treatment, and control—for hypertension, diabetes, and hyperlipidemia.[1,18,19]

Data were analyzed using R version 4.4.2 (R Foundation for Statistical Computing) and Joinpoint Regression Software version 5.4.0 (Surveillance Research Program, National Cancer Institute). All analyses accounted for the complex, multistage probability sampling design of NHANES to produce nationally representative estimates. A 2-sided *P* value <0.05 was considered statistically significant.

RESULTS

CHARACTERISTICS OF PARTICIPANTS WITH HYPERTENSION. The prevalence of hypertension in NHANES remained stable: 33.2% (95% CI: 29.4%-37.1%) in 1999-2000 and 33.4% (95% CI: 31.0%-35.8%)

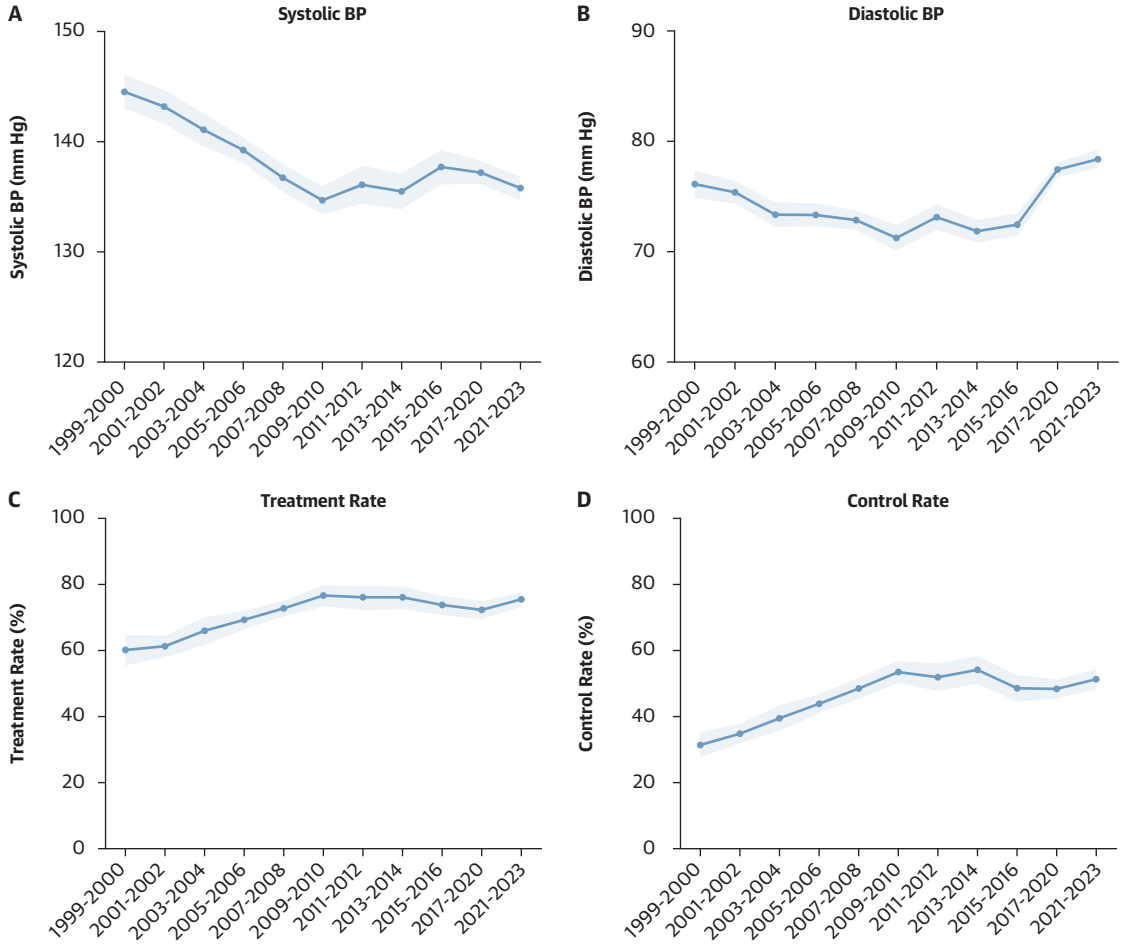
TABLE 1 Trends in Prevalence of Hypertension in NHANES

Prevalence (95% CI) (%)											
1999-2000	2001-2002	2003-2004	2005-2006	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2020	2021-2023	*P* Trend[a]
33.2 (29.4-37.1)	32.6 (30.4-34.9)	34.7 (32.3-37.2)	33.4 (30.3-36.6)	34.1 (31.9-36.4)	33.3 (31.2-35.6)	33.4 (31.0-35.8)	34.2 (32.2-36.3)	33.1 (30.1-36.2)	34.5 (32.3-36.8)	33.4 (31.0-35.8)	0.538

Estimates were age-standardized to the 2020 U.S. Census population, using age categories of 20 to 44 years (43.8%), 45 to 64 years (33.8%), and ≥65 years (22.4%). [a]Across the entire period.
NHANES = National Health and Nutrition Examination Survey.

in 2021-2023 (*P* trend = 0.538) (Table 1). Among individuals with hypertension, mean SBP and DBP decreased through 2009-2010; thereafter, SBP plateaued while DBP increased. In 2021-2023, the mean SBP and DBP levels were 136 mm Hg (95% CI: 135-137 mm Hg) and 78 mm Hg (95% CI: 78-79 mm Hg), respectively (Figures 1A and 1B). Both the treatment and control rates for hypertension increased through 2009-2010 before leveling off, with respective rates of 75.5% (95% CI: 73.3%-77.5%)

FIGURE 1 Trends in Mean Systolic and Diastolic BP and Hypertension Treatment and Control Among Patients With Hypertension



(A) Systolic BP. (B) Diastolic BP. (C) Treatment rate for hypertension. (D) Control rate for hypertension. Shaded areas denote 95% CIs. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023). BP = blood pressure.

TABLE 2 Baseline Characteristics of the Patients With Hypertension in NHANES

	1999-2000 (n = 1,535)	2001-2002 (n = 1,622)	2003-2004 (n = 1,648)	2005-2006 (n = 1,505)	2007-2008 (n = 2,103)	2009-2010 (n = 2,107)	2011-2012 (n = 1,839)	2013-2014 (n = 1,940)	2015-2016 (n = 1,971)	2017-2020 (n = 3,177)	2021-2023 (n = 2,375)
Age											
20-44 y	19.7 (2.4)	16.4 (1.0)	16.2 (1.5)	15.7 (2.4)	16.3 (0.9)	13.4 (1.2)	14.6 (1.2)	15.0 (1.0)	14.0 (1.5)	13.0 (1.2)	13.1 (1.1)
45-64 y	40.3 (1.4)	44.7 (1.8)	45.7 (1.9)	45.5 (1.4)	46.0 (1.7)	45.6 (1.1)	47.5 (1.5)	45.2 (1.5)	44.2 (1.5)	45.5 (1.1)	43.3 (1.6)
≥65 y	40.0 (1.5)	38.9 (1.7)	38.1 (1.2)	38.8 (3.0)	37.8 (1.4)	41.0 (1.3)	37.9 (1.7)	39.9 (1.3)	41.8 (1.3)	41.5 (1.7)	43.7 (1.7)
Sex											
Female	52.9 (1.9)	55.3 (1.2)	51.3 (1.5)	51.8 (1.3)	52.5 (1.1)	51.4 (1.2)	52.0 (1.7)	50.8 (1.6)	51.6 (1.4)	50.5 (1.4)	50.8 (0.9)
Male	47.1 (1.9)	44.7 (1.2)	48.7 (1.5)	48.2 (1.3)	47.5 (1.1)	48.6 (1.2)	48.0 (1.7)	49.2 (1.6)	48.4 (1.4)	49.5 (1.4)	49.2 (0.9)
Race/ethnicity											
Hispanic	11.3 (3.6)	8.2 (2.5)	7.3 (2.4)	6.1 (1.0)	8.6 (1.8)	8.9 (2.5)	9.3 (2.1)	9.8 (2.1)	11.1 (2.5)	11.5 (1.4)	13.0 (3.1)
Non-Hispanic Asian	NA	NA	NA	NA	NA	NA	3.7 (0.7)	4.2 (0.6)	4.3 (1.0)	4.9 (0.8)	5.0 (1.0)
Non-Hispanic Black	12.5 (2.5)	14.0 (2.7)	13.2 (2.5)	14.2 (2.4)	14.1 (3.0)	14.4 (1.6)	15.3 (3.4)	14.4 (2.0)	14.1 (3.0)	14.6 (2.0)	15.2 (2.2)
Non-Hispanic White	71.9 (3.4)	74.2 (2.7)	75.0 (4.0)	75.2 (2.9)	73.4 (4.0)	71.3 (3.6)	69.5 (4.4)	69.5 (3.1)	66.5 (4.2)	64.8 (3.0)	60.7 (2.3)
Other race	4.2 (1.6)	3.6 (0.6)	4.5 (0.7)	4.5 (0.9)	3.9 (0.7)	5.4 (1.2)	2.3 (0.7)	2.1 (0.5)	3.9 (0.9)	4.2 (0.7)	6.0 (0.7)
Family income-to-poverty ratio											
≥2	59.4 (3.9)	64.2 (2.1)	65.7 (3.0)	67.4 (2.3)	64.5 (2.0)	65.6 (2.5)	62.4 (3.1)	61.9 (2.7)	63.5 (3.3)	68.2 (1.6)	65.3 (2.4)
<2	40.6 (3.9)	35.8 (2.1)	34.3 (3.0)	32.6 (2.3)	35.5 (2.0)	34.4 (2.5)	37.6 (3.1)	38.1 (2.7)	36.5 (3.3)	31.8 (1.6)	34.7 (2.4)
Health insurance status											
Yes	90.4 (1.6)	91.9 (1.0)	89.0 (1.0)	90.0 (1.3)	88.1 (1.0)	88.5 (1.2)	89.3 (1.0)	89.6 (0.9)	92.2 (0.9)	91.8 (1.1)	94.3 (0.9)
No	9.6 (1.6)	8.1 (1.0)	11.0 (1.0)	10.0 (1.3)	11.9 (1.0)	11.5 (1.2)	10.7 (1.0)	10.4 (0.9)	7.8 (0.9)	8.2 (1.1)	5.7 (0.9)

Values are weighted mean or proportion (SE).
NHANES = National Health and Nutrition Examination Survey; NA = information available from the 2011-2012 cycle.

and 51.3% (95% CI: 48.2%-54.3%) in 2021-2023 (**Figures 1C and 1D**). Other baseline characteristics are presented in **Table 2**.

TRENDS IN PREVALENCE, TREATMENT, AND CONTROL OF CARDIOMETABOLIC RISK FACTORS. The prevalence of diabetes in adults with hypertension increased from 17.2% (95% CI: 14.6%-20.2%) in 1999-2000 to 27.8% (95% CI: 25.2%-30.7%) in 2021-2023 (P trend < 0.001) (**Table 3**). Among patients with hypertension and diabetes, the proportion receiving treatment for both conditions rose from 52.1% (95% CI: 40.5%-63.4%) in 1999-2000 to 69.9% (95% CI: 64.0%-75.2%) in 2009-2010 (P trend $= 0.024$) and then leveled off (71.6% in 2021-2023; 95% CI: 67.5%-75.4%; P trend $= 0.640$) (**Figure 2A**, Supplemental Table 1). The proportion of patients achieving control of both hypertension and diabetes increased from 17.6% (95% CI: 10.1%-28.8%) in 1999-2000 to 34.5% (95% CI: 27.0%-42.9%) in 2007-2008 (P trend $= 0.010$); the proportion did not increase afterward, remaining at 31.2% (95% CI: 26.5%-36.3%) in 2021-2023 (P trend $= 0.216$) (**Figure 2B**, Supplemental Table 1). Trends in treatment and control rates were consistent when hypertension and diabetes were analyzed separately, except that diabetes control rate declined since 2003-2004 (**Figure 2**, Supplemental Table 1).

The prevalence of hyperlipidemia in adults with hypertension decreased from 76.9% (95% CI: 73.8%-79.8%) in 1999-2000 to 73.1% (95% CI: 70.6%-75.4%) in 2021-2023 (P trend $= 0.008$) (**Table 3**). Among patients with hypertension and hyperlipidemia, the proportion receiving treatment for both conditions rose from 22.9% (95% CI: 18.5%-28.1%) in 1999-2000 to 42.9% (95% CI: 38.8%-47.0%) in 2005-2006 (P trend < 0.001) and subsequently plateaued (50.4% in 2021-2023; 95% CI: 47.2%-53.6%; P trend $= 0.180$) (**Figure 3A**, Supplemental Table 2). The proportion of patients achieving control of both hypertension and hyperlipidemia increased from 9.2% (95% CI: 6.5%-12.7%) in 1999-2000 to 26.7% (95% CI: 23.0%-30.8%) in 2007-2008 (P trend < 0.001). The improvement stalled in the following years, with the proportion standing at 32.3% (95% CI: 29.5%-35.2%) in 2021-2023 (P trend $= 0.109$) (**Figure 3B**, Supplemental Table 2). Hypertension and hyperlipidemia, when examined

TABLE 3 Trends in Prevalence of Cardiometabolic Risk Factors Among Patients With Hypertension

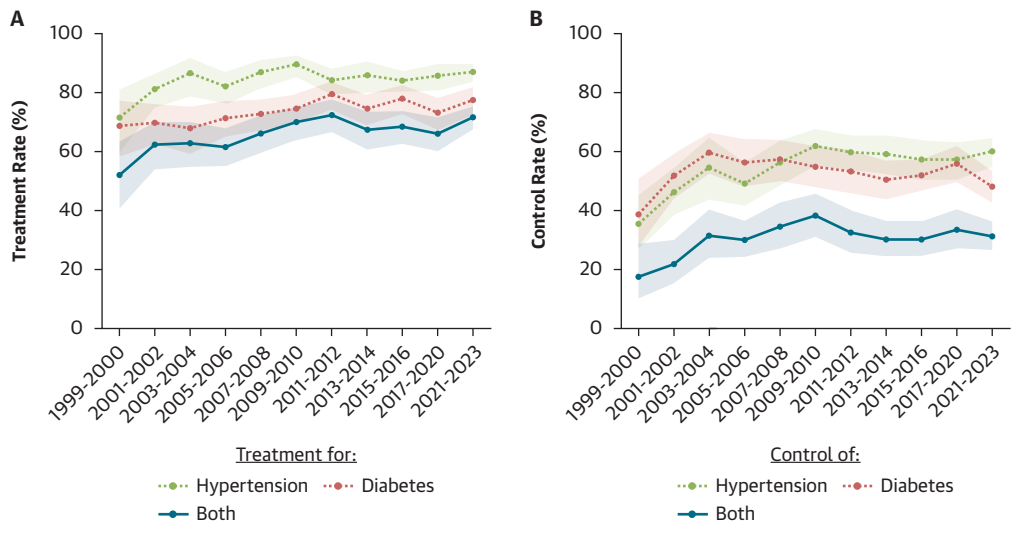
	Prevalence (95% CI) (%)											
	1999-2000	2001-2002	2003-2004	2005-2006	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2020	2021-2023	*P* Trend[a]
Diabetes	17.2 (14.6-20.2)	17.8 (15.4-20.4)	20.6 (17.7-23.9)	20.4 (18.3-22.7)	23.3 (20.3-26.6)	25.0 (22.9-27.1)	24.2 (21.1-27.5)	25.6 (22.9-28.6)	27.0 (23.9-30.4)	28.3 (26.2-30.5)	27.8 (25.2-30.7)	<0.001
Hyperlipidemia	76.9 (73.8-79.8)	73.7 (70.2-76.9)	77.1 (74.7-79.2)	77.2 (74.4-79.9)	74.5 (72.0-77.0)	75.1 (71.1-78.8)	73.4 (70.3-76.2)	74.6 (70.7-78.1)	73.3 (69.2-77.0)	71.0 (67.6-74.1)	73.1 (70.6-75.4)	0.008
Concurrent diabetes and hyperlipidemia	12.5 (10.6-14.7)	13.6 (11.5-16.1)	17.4 (14.4-20.8)	16.5 (14.4-18.9)	17.9 (15.4-20.7)	19.9 (17.9-22.1)	18.3 (15.6-21.3)	19.6 (17.3-22.1)	19.4 (16.6-22.4)	20.4 (18.5-22.5)	21.3 (19.0-23.8)	<0.001
Obesity	43.7 (40.3-47.1)	40.6 (37.7-43.6)	42.3 (38.5-46.1)	44.0 (40.8-47.3)	44.9 (41.8-48.1)	49.9 (46.8-52.9)	46.7 (42.5-50.9)	48.9 (46.3-51.5)	51.5 (47.7-55.3)	51.7 (48.9-54.4)	52.4 (50.1-54.7)	<0.001
Current smoking	15.2 (12.7-18.0)	16.7 (14.3-19.3)	16.7 (14.5-19.2)	18.4 (15.8-21.4)	17.3 (15.1-19.7)	14.2 (12.2-16.4)	15.4 (12.7-18.6)	17.4 (14.9-20.1)	18.6 (15.2-22.5)	16.0 (14.0-18.2)	15.3 (12.8-18.1)	0.789
High-risk drinking	7.4 (5.1-10.7)	7.6 (6.0-9.6)	6.5 (4.8-8.9)	8.5 (6.7-10.7)	5.8 (4.5-7.4)	8.3 (6.4-10.6)	11.6 (9.3-14.4)	8.9 (6.6-12.0)	9.5 (6.6-13.5)	7.8 (6.3-9.6)	11.2 (9.3-13.3)	0.024

Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023). [a]Across the entire period.

individually, exhibited consistent trends in treatment and control rates, apart from a continuous increase in hyperlipidemia control rate over the study period (**Figure 3**, Supplemental Table 2).

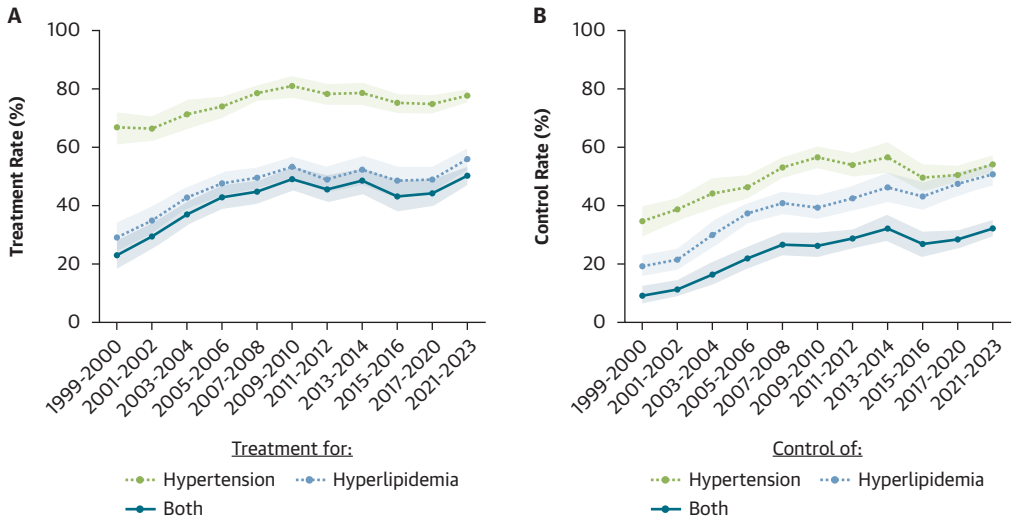
The prevalence of concurrent diabetes and hyperlipidemia in adults with hypertension nearly doubled from 12.5% (95% CI: 10.6%-14.7%) in 1999-2000 to 21.3% (95% CI: 19.0%-23.8%) in 2021-2023 (*P* trend < 0.001) (**Table 3**). Among patients with hypertension, diabetes, and hyperlipidemia, the proportion receiving treatment for all 3 conditions increased from 26.7% (95% CI: 19.9%-34.9%) in 1999-2000 to 55.4% (95% CI: 45.6%-64.8%) in 2007-2008 (*P* trend < 0.001) and plateaued afterward (62.1% in 2021-2023; 95% CI: 56.6%-67.2%; *P* trend = 0.492) (**Figure 4A**, Supplemental Table 3). The proportion of patients achieving control of all 3 conditions rose from 7.8% (95% CI: 3.1%-18.5%) in 1999-2000 to 23.3% (95% CI: 17.8%-29.8%) in 2007-2008 (*P* trend < 0.001). The proportion subsequently leveled off, remaining at 26.3% (95% CI: 20.8%-32.6%) in 2021-2023 (*P* trend = 0.769) (**Figure 4B**,

FIGURE 2 Trends in Treatment and Control Rates Among Patients With Hypertension and Concurrent Diabetes



(A) Treatment rate. (B) Control rate. Shaded areas denote 95% CIs. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023).

FIGURE 3 Trends in Treatment and Control Rates Among Patients With Hypertension and Concurrent Hyperlipidemia

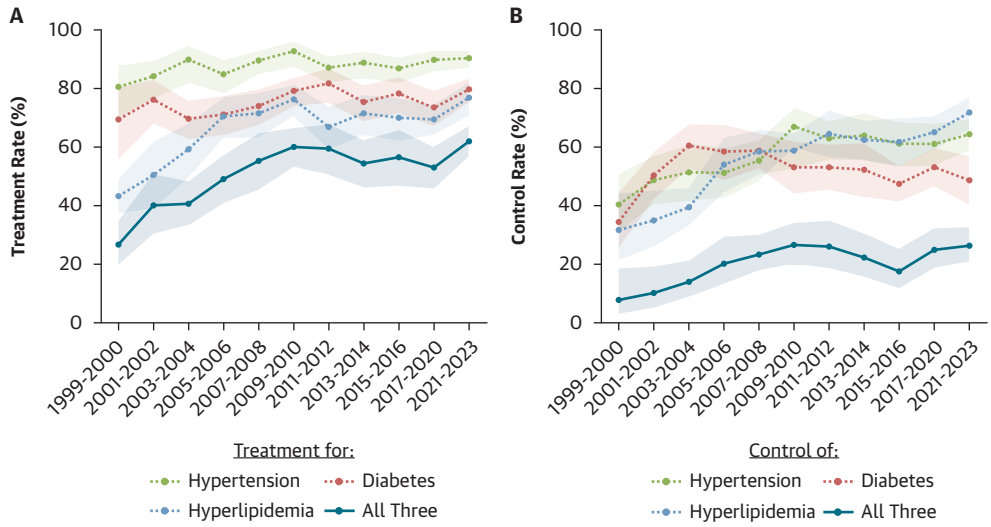


(A) Treatment rate. (B) Control rate. Shaded areas denote 95% CIs. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023).

Supplemental Table 3). Treatment and control rates generally showed similar trends when hypertension, diabetes, and hyperlipidemia were assessed separately—except that the diabetes treatment rate remained unchanged, the diabetes control rate declined since 2003-2004, and the hyperlipidemia control rate continued to increase (**Figure 4**, Supplemental Table 3).

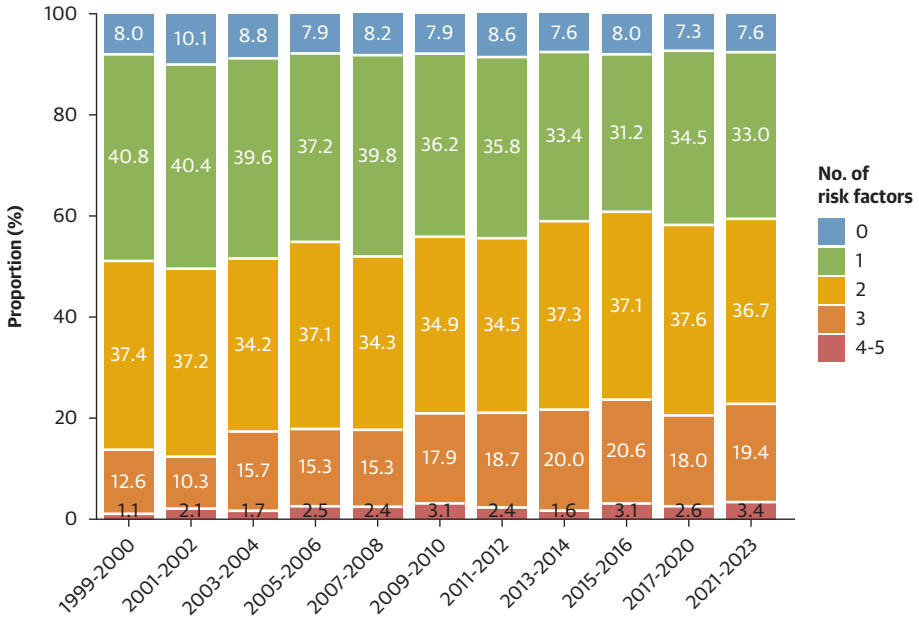
The prevalence of obesity in adults with hypertension increased from 43.7% (95% CI: 40.3%-47.1%)

FIGURE 4 Trends in Treatment and Control Rates Among Patients With Hypertension and Concurrent Diabetes and Hyperlipidemia



(A) Treatment rate. (B) Control rate. Shaded areas denote 95% CIs. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023).

FIGURE 5 Trends in Number of Cardiometabolic Risk Factors Among Patients With Hypertension



Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023).

in 1999-2000 to 52.4% (95% CI: 50.1%-54.7%) in 2021-2023 (P trend < 0.001). The prevalence of current smoking remained stable: 15.2% (95% CI: 12.7%-18.0%) in 1999-2000 and 15.3% (95% CI: 12.8%-18.1%) in 2021-2023 (P trend = 0.789). The prevalence of high-risk drinking increased from 7.4% (95% CI: 5.1%-10.7%) in 1999-2000 to 11.2% (95% CI: 9.3%-13.3%) in 2021-2023 (P trend = 0.024) (Table 3).

TABLE 4 Estimated Number of Patients With Hypertension by Comorbid Cardiometabolic Risk Factors and by Number of Risk Factors, 2021-2023

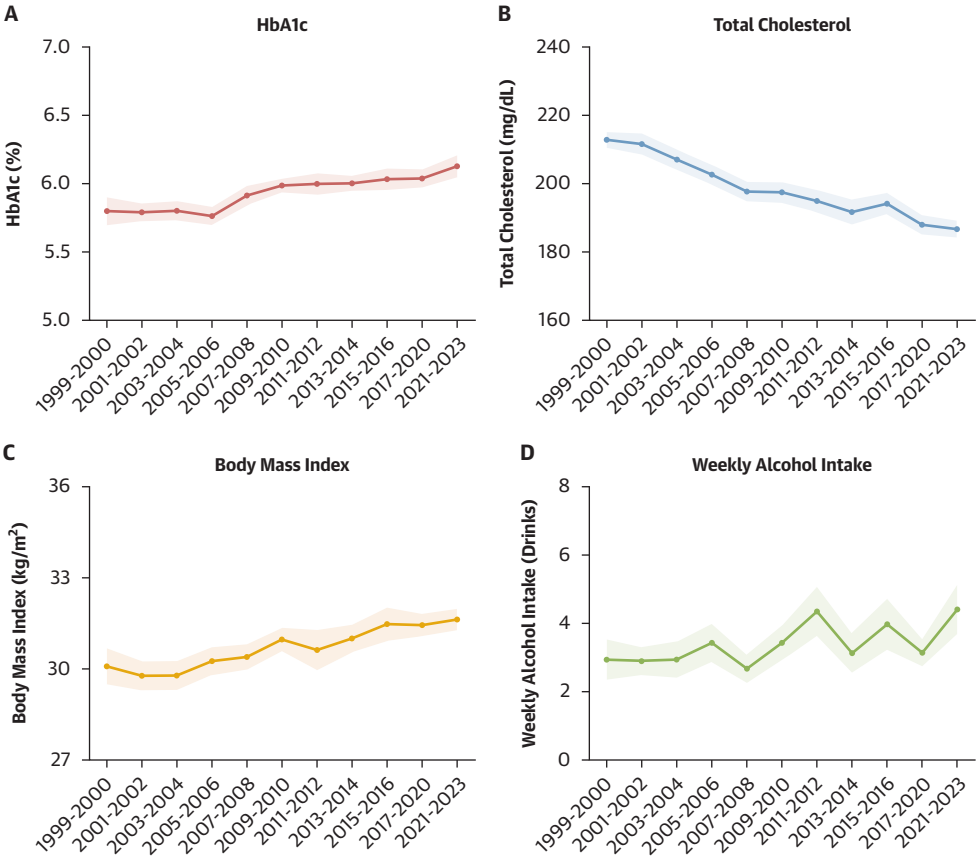
	Patients With Hypertension
Comorbid cardiometabolic risk factor	
Diabetes	23,221,109
Hyperlipidemia	60,913,009
Concurrent diabetes and hyperlipidemia	17,774,707
Obesity	43,713,469
Current smoking	12,735,731
High-risk drinking	9,317,053
Number of cardiometabolic risk factors	
0	6,297,662
1	27,426,510
2	30,611,688
3	16,237,783
4	2,345,325
5	490,283

Numbers of patients were estimated using the 2020 U.S. Census population and prevalence estimates from the August 2021-August 2023 cycle.

The proportion of adults with hypertension who had no cardiometabolic risk factors was mostly below 10% across survey cycles, whereas the proportion who had ≥2 cardiometabolic risk factors increased from 51.1% (95% CI: 46.8%-55.5%) in 1999-2000 to 59.5% (95% CI: 56.5%-62.4%) in 2021-2023 (P trend < 0.001) (Figure 5). Table 4 shows the estimated number of patients with hypertension by comorbid cardiometabolic risk factors and by number of risk factors in 2021-2023. Trends in mean levels of cardiometabolic measures among adults with hypertension are illustrated in Figure 6.

SUBGROUP AND SECONDARY ANALYSES. Figure 7 depicts sex- and race/ethnicity-stratified trends in the proportions of patients with hypertension, diabetes, and hyperlipidemia who were receiving treatment and achieving control of all 3 conditions. Among the patients pooled from the 2017-March 2020 and August 2021-August 2023 cycles, the proportion receiving treatment for all 3 conditions tended to be lower in younger adults, females, and uninsured individuals (Figure 8A). The proportion achieving

FIGURE 6 Trends in Mean Levels of Cardiometabolic Measures Among Patients With Hypertension



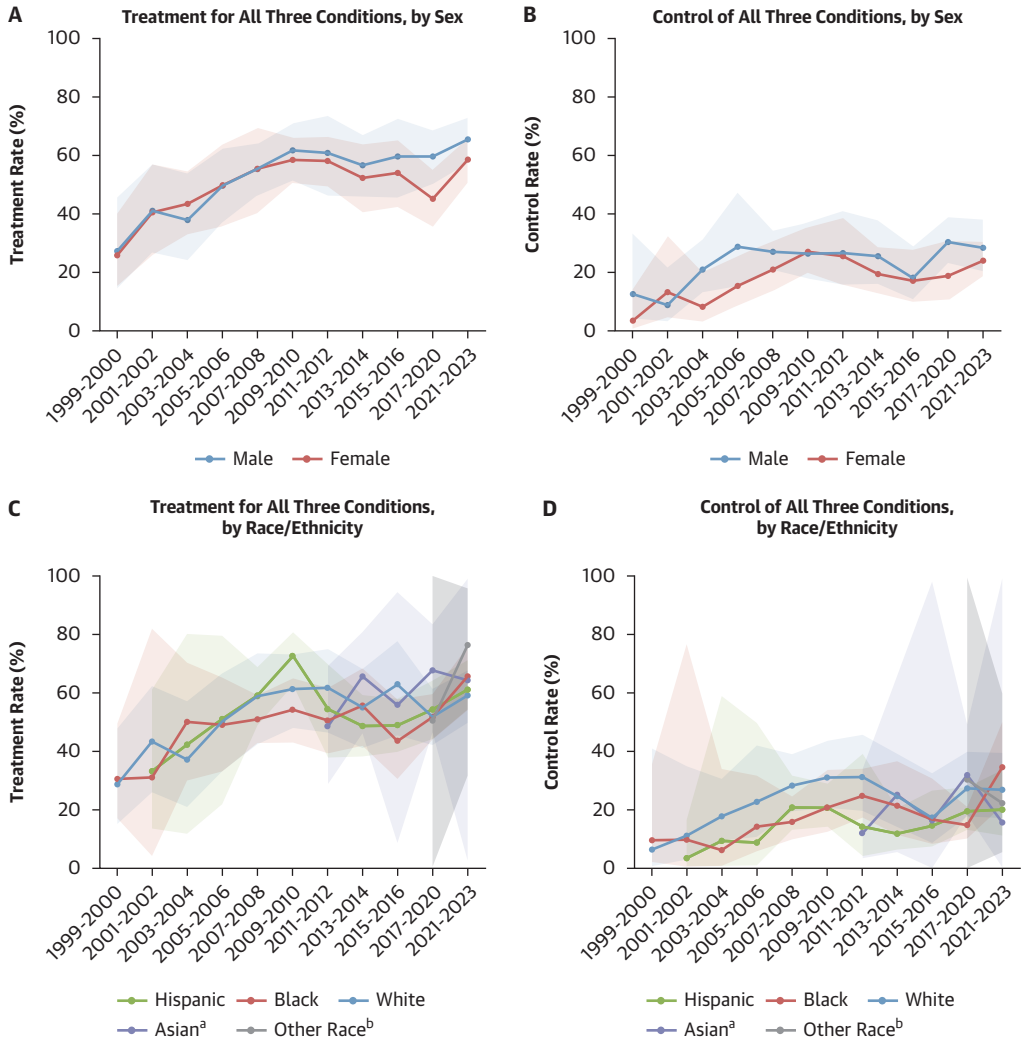
(A) HbA1c. (B) Total cholesterol. (C) Body mass index. (D) Weekly alcohol intake. Shaded areas denote 95% CIs. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023). HbA1c = glycosylated hemoglobin.

control of all 3 conditions was likewise lower in females, those with a family income-to-poverty ratio <2, and uninsured individuals (**Figure 8B**).

In individuals with hypertension, renin-angiotensin system blocker and beta-blocker use increased through 2017-2020, while potassium-sparing diuretic use decreased (**Figure 9A**). Among those with concurrent diabetes, use of metformin, dipeptidyl peptidase-4 inhibitors, glucagon-like peptide-1 (GLP-1) receptor agonists, and sodium-glucose cotransporter 2 inhibitors increased, whereas sulfonylurea use decreased and thiazolidinedione use peaked in 2003-2004 before declining (**Figure 9B**). Statin use increased over time among those with concurrent hyperlipidemia (**Figure 9C**). Monotherapy was the most common form of BP-, glucose-, and lipid-lowering therapy across all survey cycles (**Figure 10**).

SENSITIVITY ANALYSES. First, the trends in the examined measures were mostly consistent when hypertension and its control were defined using the BP threshold of 130/80 mm Hg (Supplemental Tables 4 and 5). Second, expanding the definitions of diabetes and hyperlipidemia to include self-reported medication use minimally influenced our main findings (Supplemental Tables 6 and 7). Third, truncating the trend analyses at the 2015-2016 cycle did not affect either the number of breakpoints or the stagnation of treatment and control rates after the breakpoints, although the breakpoint locations shifted slightly (Supplemental Table 8). Fourth, the trends estimated from natural spline models were graphically comparable to those estimated from the Joinpoint trend analyses (Supplemental Figures 2 to 5). Fifth, in a care cascade, the diagnosis rates for hypertension and hyperlipidemia increased until

FIGURE 7 Subgroup Analysis of Trends in Treatment and Control Rates Among Patients With Hypertension and Concurrent Diabetes and Hyperlipidemia



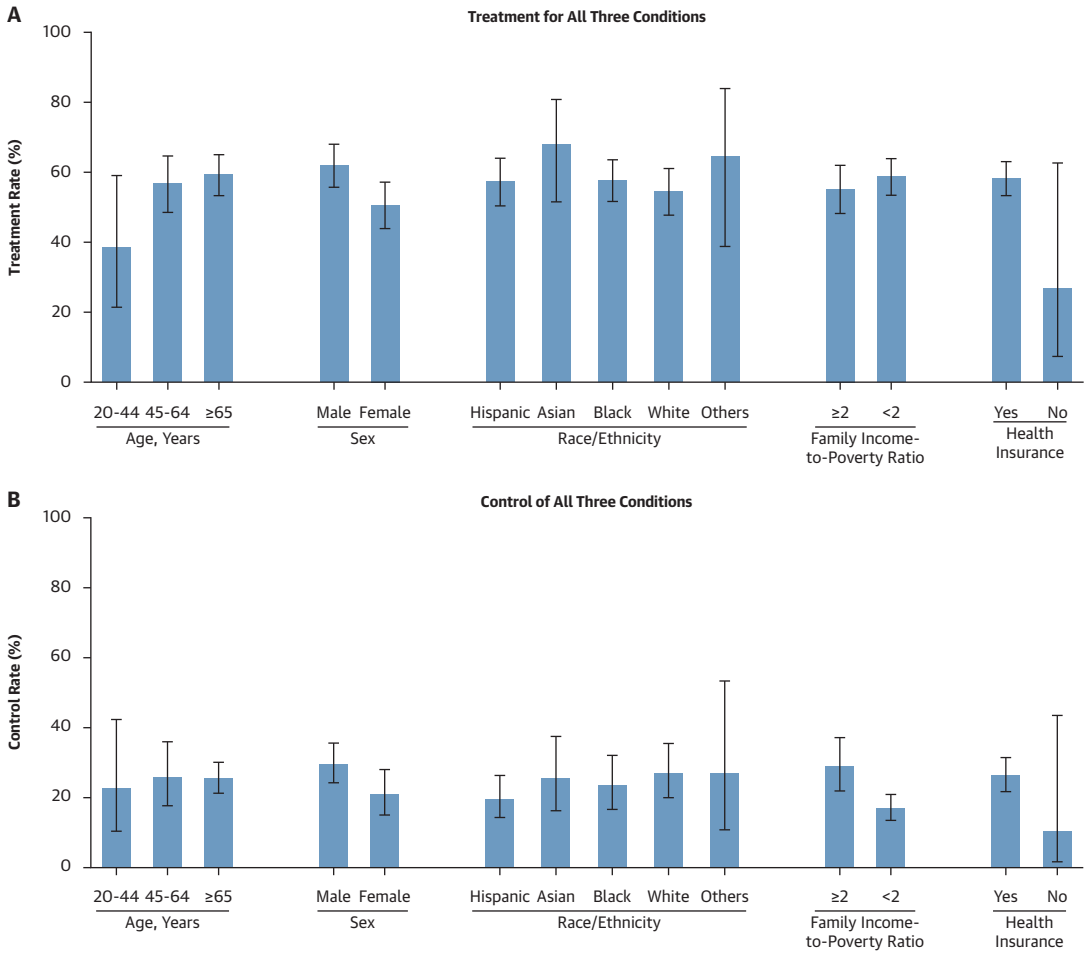
(A) Treatment rate by sex. (B) Control rate by sex. (C) Treatment rate by race/ethnicity. (D) Control rate by race/ethnicity. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023). [a]Information available from the 2011-2012 cycle. [b]Excluded through the 2015-2016 cycle due to small sample size.

around 2010 and then plateaued, whereas the diagnosis rate for diabetes remained largely unchanged. Trends in the subsequent stages of treatment and control were all broadly consistent with our main findings (Figure 11).

DISCUSSION

Since 1999, the prevalence of cardiometabolic risk factors among U.S. adults with hypertension has increased overall. Currently, about 1 in 4 patients with hypertension have diabetes, 3 in 4 have hyperlipidemia, and 1 in 5 have both diabetes and hyperlipidemia. Treatment and control of these conditions improved during the 2000s, but progress has plateaued in subsequent years. Notably, the proportion of individuals with hypertension, diabetes, and hyperlipidemia achieving control of all 3 conditions did not exceed 30% at any point during the study period. These findings highlight ongoing gaps

FIGURE 8 Subgroup Analysis of Patients With Hypertension and Concurrent Diabetes and Hyperlipidemia Pooled from the 2 Most Recent Survey Cycles (2017-March 2020 and August 2021-August 2023)



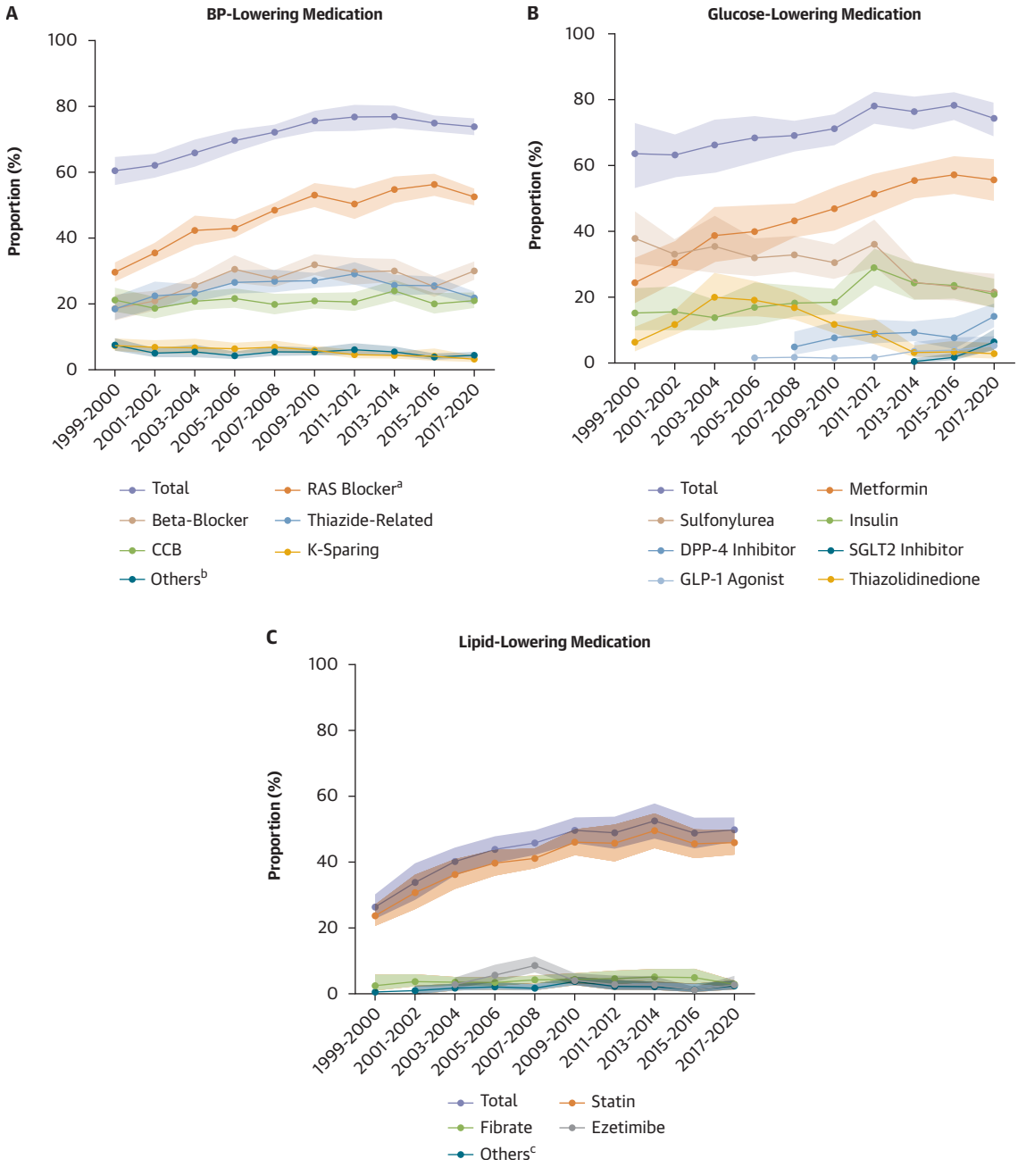
(A) Treatment rate across subgroups. (B) Control rate across subgroups. Error bars denote 95% CIs. Except for analyses stratified by age, estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023).

in the management of hypertension and comorbid cardiometabolic risk factors, which may be contributing to the high and rising burden of hypertension-related mortality in the United States.

In parallel with prior studies,[7,20] we found that hypertension control rate remained around 50% to 60% over the past decade. The rates were comparable when hypertension coexisted with diabetes, hyperlipidemia, or both, implying an apparent failure to achieve better hypertension control in those at further increased risk of cardiovascular events. Of note, the gap between hypertension treatment and control rates was most pronounced in individuals with concurrent diabetes and hyperlipidemia, who represent over 20% of the hypertension population. This suggests that patients with multiple risk factors face greater challenges in achieving hypertension control. More active use of combination therapy may help address this issue,[21] as monotherapy remained the most common approach to BP-lowering treatment throughout the study period.

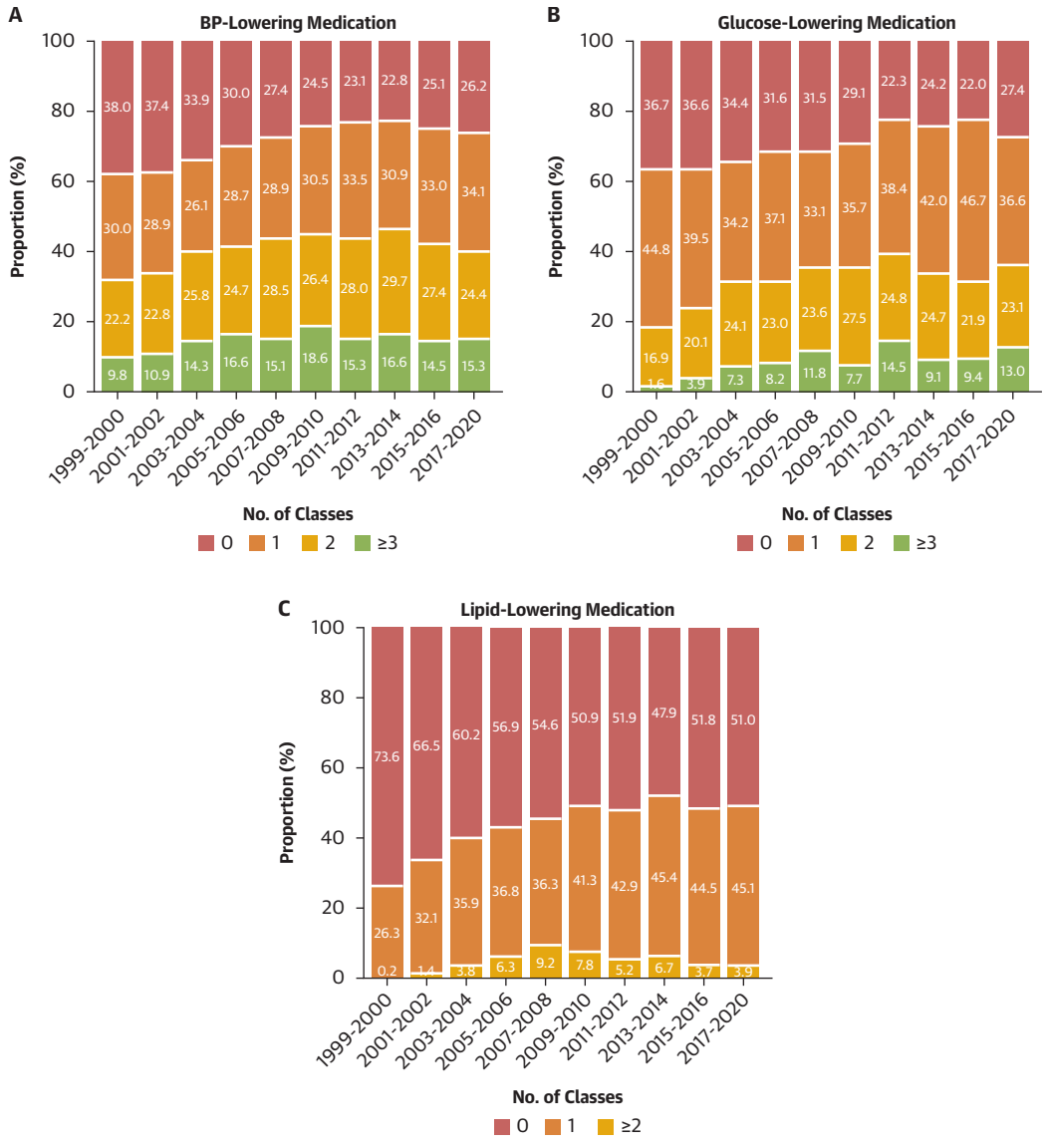
The recent flattening of diabetes treatment and worsening of diabetes control among individuals with hypertension and diabetes emphasize the need to improve antidiabetic treatment uptake in this population. To facilitate this, physicians caring for patients with hypertension should be attentive to the rising prevalence of diabetes in these patients and proactively screen for it when clinically suspected.

FIGURE 9 Trends in Class-Specific Use of BP-, Glucose-, and Lipid-Lowering Medications Among Patients With Hypertension



(A) Class-specific use of blood pressure (BP)-lowering medication among patients with hypertension. (B) Class-specific use of glucose-lowering medication among patients with hypertension and concurrent diabetes. (C) Class-specific use of lipid-lowering medication among patients with hypertension and concurrent hyperlipidemia. Shaded areas denote 95% CIs. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023). [a]Includes angiotensin-converting enzyme inhibitor and angiotensin receptor blocker. [b]Include alpha-1 blocker, alpha-2 agonist, vasodilator, and renin inhibitor. [c]Include proprotein convertase subtilisin/kexin type 9 inhibitor, nicotinic acid, omega-3 fatty acid, icosapent ethyl, and bile acid binding resin. CCB = calcium-channel blocker; DPP-4 = dipeptidyl peptidase-4; GLP-1 = glucagon-like peptide-1; RAS = renin-angiotensin system; SGLT2 = sodium-glucose cotransporter 2.

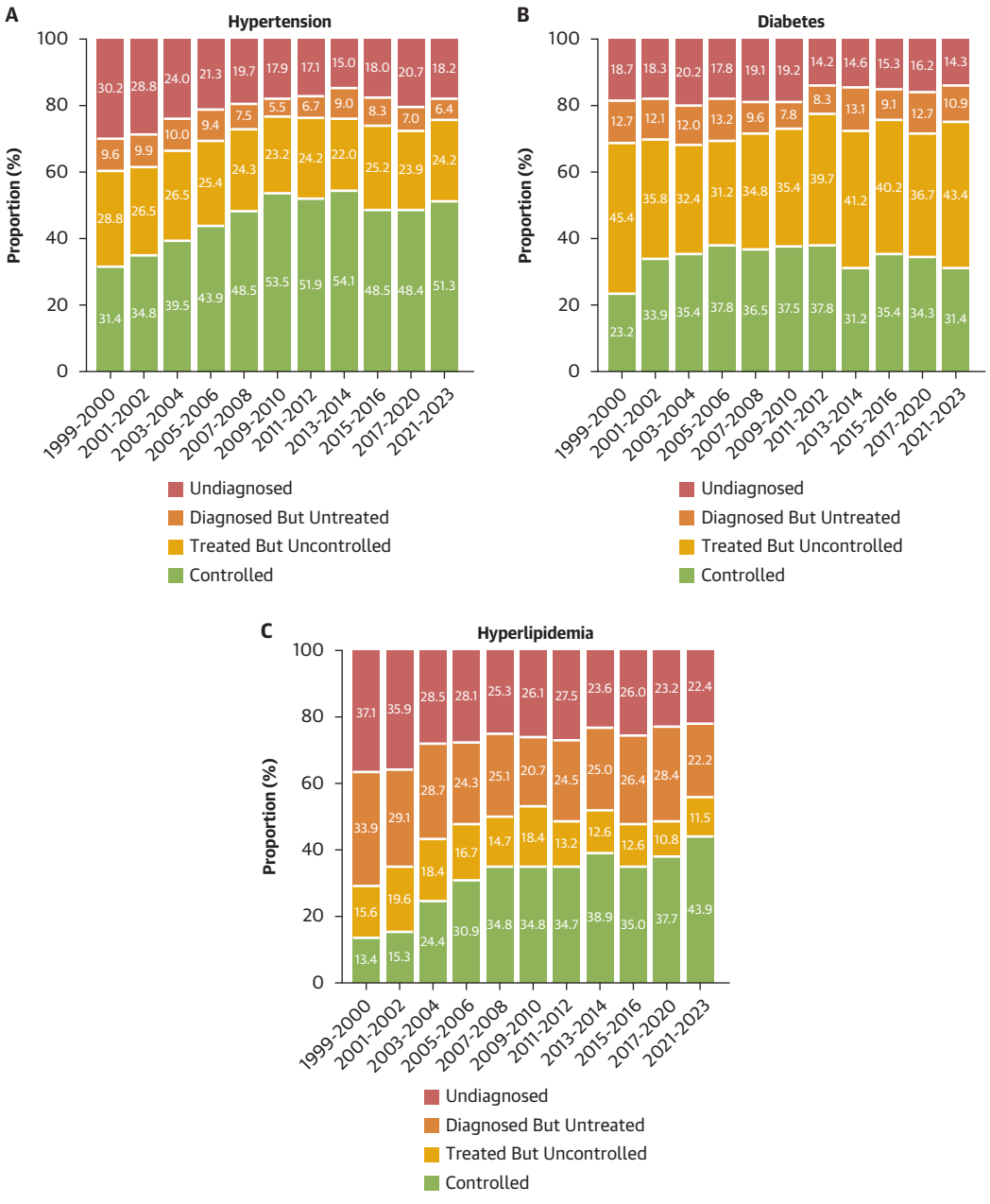
FIGURE 10 Trends in Number of Medication Classes Among Patients With Hypertension



(A) Number of blood pressure (BP)–lowering medication classes among patients with hypertension. (B) Number of glucose-lowering medication classes among patients with hypertension and concurrent diabetes. (C) Number of lipid-lowering medication classes among patients with hypertension and concurrent hyperlipidemia. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023).

The discrepancy between trends in diabetes treatment and control also suggests that there may be factors beyond treatment that are contributing to worsening diabetes control, such as a rising prevalence of coexisting obesity.[6,22] By contrast, the continued rise in hyperlipidemia control rate despite a plateau in treatment rate might reflect improvements in health-related behaviors or broader implementation of novel therapeutic modalities (eg, long-acting injectable agents).[23,24] Although our definition of hyperlipidemia control does not fully align with current preventive approaches focusing on risk-based low-density lipoprotein cholesterol lowering,[25] sustained improvement in this pragmatic measure of lipid control may still provide insight into strategies to

FIGURE 11 Trends in a Care Cascade of Diagnosis, Treatment, and Control for Hypertension, Diabetes, or Hyperlipidemia



(A) Hierarchical proportions of patients with hypertension who were diagnosed, treated, and controlled for hypertension. (B) Hierarchical proportions of patients with hypertension and concurrent diabetes who were diagnosed, treated, and controlled for diabetes. (C) Hierarchical proportions of patients with hypertension and concurrent hyperlipidemia who were diagnosed, treated, and controlled for hyperlipidemia. Estimates were age-standardized to the weighted population of nonpregnant adults ≥20 years of age with hypertension in the most recent survey cycle (August 2021-August 2023).

reverse the stagnating or worsening trends in hypertension and diabetes control.

The rapid increase in patients with hypertension and concurrent diabetes and hyperlipidemia is concerning, as they face a markedly elevated risk of cardiovascular disease.[11] Further, nearly three-quarters of these individuals fail to achieve control of at least 1 of the 3 conditions, placing this

expanding population at even greater risk.[26] Future efforts should focus on addressing this unmet need, with particular attention to subgroups that are lagging in treatment and control. Young adults and females, who exhibited lower treatment rates than their counterparts, may represent key demographic groups for targeted interventions.[27,28] In addition, poorer control documented among individuals with low family income or those without health insurance underscores the importance of overcoming structural barriers to care in socioeconomically disadvantaged populations.[29]

Our findings indicate that diabetes and obesity are becoming increasingly common among patients with hypertension, with the prevalence of obesity now surpassing 50%. Given the frequent coexistence of hypertension, diabetes, and obesity and their joint contribution to adverse health outcomes,[30,31] future preventive efforts should ideally target these conditions simultaneously. In this light, the observed increase in GLP-1 receptor agonist use represents a promising step toward improving cardiovascular-kidney-metabolic health in the United States.[32] The overall low prescription rate of GLP-1 receptor agonists and persistent disparities in their use remain key challenges,[33] highlighting the need to identify and address obstacles hindering their wider adoption.

STUDY STRENGTHS AND LIMITATIONS. Our analysis of NHANES spanning more than 2 decades—including the postpandemic period—provides a comprehensive view of the increasing burden and clustering of cardiometabolic risk factors among U.S. adults with hypertension. The documented stagnation in the joint management of hypertension, diabetes, and hyperlipidemia, along with diverging trends for each individual condition, represents an important observation that can inform public health initiatives.

This study has certain limitations. First, the 2017 American College of Cardiology/American Heart Association guideline's revision of the BP threshold for hypertension—from 140/90 mm Hg to 130/80 mm Hg[17]—may have influenced practice patterns. However, temporal trends in the examined measures were largely unchanged when hypertension and its control were redefined using the BP threshold of 130/80 mm Hg in a sensitivity analysis. Second, NHANES transitioned from auscultatory to oscillometric BP measurement in the 2017-2018 cycle. Although truncating the analyses at the 2015-2016 cycle did not materially alter the trends, some uncertainty remains regarding the effects introduced by this transition. Third, we defined treatment of hypertension, diabetes, and hyperlipidemia based on self-reports. While this may raise concerns about validity, agreement between self-reported medication use and pill bottle review was high among participants with available data—86.8% for hypertension treatment, 85.4% for diabetes treatment, and 88.1% for hyperlipidemia treatment—supporting the robustness of our approach. Fourth, response rates in NHANES have been declining. To minimize nonresponse bias, the NCHS implemented additional weighting adjustments beginning with the 2017-2018 cycle.[34] Fifth, the large number of statistical tests may have increased the risk of false positives. Our findings should be interpreted in the context of the descriptive nature of the study.

CONCLUSIONS

The prevalence of concurrent diabetes and hyperlipidemia among U.S. adults with hypertension has nearly doubled since 1999, largely driven by an increase in diabetes. Only 1 in 4 individuals with hypertension, diabetes, and hyperlipidemia has all 3 conditions controlled—a level that has not improved in more than a decade. Disrupting this stagnation may be essential for reducing the burden of hypertension-related morbidity and mortality in the United States.

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Blackstone Life Sciences, Bristol Myers Squibb, Creative Education Concepts, CRISPR Therapeutics, Eli Lilly & Co., Esperion Therapeutics, Foresite Capital, Foresite Labs, Genentech/Roche, GV, HeartFlow, Magnet Biomedicine, Merck, Novartis, Novo Nordisk, TenSixteen Bio, and Tourmaline Bio; has equity in Bolt, Candela, Mercury, MyOme, Parameter Health, Preciseli, and TenSixteen Bio; and his spouse is an employee of Vertex Pharmaceuticals, all unrelated to the present work. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

ADDRESS FOR CORRESPONDENCE: Dr Eric A. Secemsky, Richard A. and Susan F. Smith Center for Outcomes Research in Cardiology, Beth Israel Deaconess Medical Center, Harvard Medical School, 375 Longwood Avenue, Suite 440, Boston, Massachusetts 02215, USA. E-mail: esecemsk@bidmc.harvard.edu.

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KEY WORDS cardiometabolic risk factor, control, hypertension, prevalence, treatment

APPENDIX For supplemental tables and figures, please see the online version of this paper.