



Age-stratified prevalence, treatment status, and associated factors of hypertension among US adults following application of the 2017 ACC/AHA guideline

Gulam Muhammed Al Kibria¹ · Amy Nemirovsky¹ · Atia Sharmin² · Brendan Day¹

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Abstract

The 2017 American College of Cardiology/American Heart Association Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults reduced the systolic/diastolic blood pressure thresholds to define hypertension, including recommendations about treatment initiations and goals. We estimated the age-stratified prevalence, treatment status, and factors associated with hypertension among US adults aged ≥ 20 years based on this guideline. This cross-sectional study used the 2011–2016 National Health and Nutrition Examination Survey data. The primary outcomes were the presence and treatment status of hypertension. Among 16,103 participants, the proportions (95% confidence interval) of hypertensive, treatment-indicated, untreated individuals among treatment-indicated, and treatment goals not met among treated for hypertension by age groups were, respectively, 17.4% (15.8–19.1), 6.9% (6.1–7.8), 67.6% (61.0–73.5), and 58.6% (46.1–70.2) among 20–34 years; 39.2% (37.0–41.5), 24.4% (22.4–26.5), 41.8% (37.7–46.0), and 50.4% (44.7–56.1) among 35–49 years; 62.3% (60.1–64.6), 51.4% (49.0–53.8), 31.0% (28.2–34.0), and 51.9% (47.6–56.1) among 50–64 years; 77.7% (75.3–79.8), 77.0% (74.7–79.2), 27.0% (24.3–29.8), and 63.1% (59.4–66.5) among ≥ 65 years; and 46.8% (45.4–48.3), 36.9% (35.4–38.5), 33.2% (30.9–35.5), and 56.7% (54.1–59.3) among overall population. Despite some dissimilarities, the prevalence, treatment eligibility, and odds of hypertension were higher among non-Hispanic blacks and among people with high cholesterol, low high-density lipoprotein, chronic kidney disease, diabetes, increased body weight, and low leisure-time physical activity in all age strata. The prevalence and treatment eligibility were high among adults from all age groups; however, a significant proportion of participants, especially those who were younger, had blood pressure levels above the treatment goals or were untreated. Addressing the associated characteristics from a younger age may help prevent the complications of hypertension.

Introduction

Cardiovascular disease (CVD) is one of the leading causes of death in the United States [1], and uncontrolled hypertension is the primary risk factor for CVD [2–4]. As per the

2017 American College of Cardiology/American Heart Association (ACC/AHA) Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults' prevalence estimate by Muntner et al., more than 45% of US adults (aged ≥ 20 years) could be hypertensive [5]. Lowering the systolic/diastolic blood pressure (SBP/DBP) cutoffs from $\geq 140/90$ mm Hg to $\geq 130/80$ mm Hg has changed the prevalence from previous estimates [5, 6]. Furthermore, the new guideline has modified the recommendations and goals of treatment [6]. The estimated proportion of people with unmet treatment goals has also been found to be high among treated people [5].

The prevalence, treatment indications, and risks of hypertension vary according to sociodemographic and behavioral characteristics. Age is an established risk factor for hypertension; older people usually have a higher likelihood of developing hypertension [5, 6] due to the changes

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✉ Gulam Muhammed Al Kibria
gkibria1@outlook.com

¹ Department of Epidemiology and Public Health, University of Maryland School of Medicine, Baltimore, MD 21201, USA

² School of Community Health and Policy, Morgan State University, Baltimore, MD 21251, USA

in blood vessel walls that occur with aging [7]. For instance, Muntner et al. found the prevalence of hypertension as 24.0, 47.1, 66.6, 75.6, and 82.3% among people aged 20–44, 45–54, 55–64, 65–74, and ≥ 75 years, respectively [5]. Awareness and control levels also differ with age. In addition, prevalence, awareness, treatment, and control could differ by sex, race, body mass index (BMI), and other comorbidities [5, 6, 8, 9].

The application of the 2017 ACC/AHA guideline could significantly reduce the burden of future CVD events [6, 10, 11]. Stratifying the prevalence, treatment patterns, and associated factors of hypertension by age could help formulate age-specific prevention strategies if these factors differ between age groups. Although earlier studies have investigated the awareness [12] and control [9] of hypertension according to the new guideline in terms of the overall prevalence [5, 6, 8], the age-stratified prevalence of hypertension and the prevalence of pharmacotherapy-indicated, and untreated hypertensive individuals were not estimated. Furthermore, the risk factors for hypertension were not stratified by age. Considering the significant changes in prevalence between individuals of varying age categories following the adoption of the new guideline [5, 6, 8], the factors associated with hypertension in these groups may differ compared with those in the overall population. Due to the clinical and public health significance of hypertension, these estimates would be helpful for prevention, treatment, and control purposes.

Using the 2017 ACC/AHA guideline, this study attempted to identify and fill these existing gaps in the literature by obtaining the following age-stratified and overall estimates according to sociodemographic and clinical characteristics among US adults: the prevalence of hypertension; the proportion of people eligible for antihypertensive treatment; the proportion of untreated individuals among treatment-eligible individuals; and the proportion of individuals with unmet treatment goals among treated (i.e., taking antihypertensive medication) persons. In addition, age-stratified factors associated with hypertension were determined.

Methods

Data source

The present study utilized data from the 2011–2016 National Health and Nutrition Examination Survey (NHANES). This biennial cross-sectional survey aims to obtain nationally representative samples of non-institutionalized US people using a multistage cluster-sampling design. Details of the NHANES, including the survey design, methodologies, and datasets are available

elsewhere [13–16]. Datasets were downloaded and merged according to the identification numbers. All respondents provided written informed consent. The Ethics Review Board of the National Center for Health Statistics Research approved the protocols [17].

Blood pressure

Respondents aged ≥ 20 years with ≥ 3 BP measurements were eligible for analysis. The mean of the first three measurements was used to categorize BP. Trained physicians used factory-calibrated Baumanometer® mercury true gravity wall model sphygmomanometers with appropriate cuff sizes to measure BP while the participants were seated in mobile examination centers. Before the measurements, participants remained in a seated position for 5 min [18].

Individuals with $SBP/DBP \geq 130/80$ mm Hg or who currently reported taking antihypertensive drugs were considered hypertensive. Stage 1 and stage 2 hypertension were defined as $SBP/DBP 130–139/80–89$ and $\geq 140/90$ mm Hg, respectively, while elevated BP was considered when the SBP was 120–129 mm Hg with a normal DBP (i.e., < 80 mm Hg) [6].

Study variables

Participants reported their age (in years), gender (i.e., male or female), and race. Due to different treatment indications and goals, individuals with ≥ 65 years of age were considered as a separate stratum. Other age groups were stratified into three approximately equal-sized strata: 20–34, 35–49, and 50–64 years.

Cholesterol levels from 200–239 and ≥ 240 mg/dl were stratified into ‘borderline elevated’ and ‘high’ cholesterol levels, respectively. Participants who reported taking cholesterol-lowering drugs were also grouped in the high-cholesterol group. High-density lipoprotein (HDL) cholesterol levels were categorized as low if the concentration was < 40 mg/dl for men and < 50 mg/dl for women. Participants reported if they were ever diagnosed with prediabetes or diabetes by a physician. The glomerular filtration rate (GFR) was obtained using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation. Persons with an albumin-creatinine ratio ≥ 30 mg/g or a GFR < 60 ml/min per 1.73 m^2 were categorized as having CKD [19].

Myocardial infarction, coronary heart disease, stroke, or heart failure was considered as CVD events. The 10-year predicted CVD risk was calculated with Pooled Cohort Risk equations among people without a history of CVD events [20]. Although the Pooled Cohort Risk equations are recommended to calculate CVD risk for individuals aged 40–79 years, to conform to the 2017 ACC/AHA guideline, these equations were used for all age groups in this study

because the equations were the only currently available tools [5, 20]. A person was considered to have high CVD risk if s/he had a history of CVD or had a $\geq 10\%$ 10-year CVD risk [5, 6].

The BMI was calculated as ‘weight in kilograms’ divided by ‘height in meters squared’ and was categorized as underweight/normal weight (i.e., $< 25 \text{ kg/m}^2$), overweight (i.e., $25\text{--}29.9 \text{ kg/m}^2$), and obese (i.e., $\geq 30 \text{ kg/m}^2$). In NHANES, the family income to poverty ratio is determined from the ratio of the family’s income to the poverty thresholds according to the number of family members. A higher ratio indicates that the participant is from a wealthier family. This ratio was categorized into ‘ < 2 ’ and ‘ ≥ 2 ’ [9, 21]. Participants reported the usual amount of time they spent doing moderate and vigorous recreational physical activity (PA) in a week. Minutes spent performing vigorous PA were multiplied by 2, and this number was added to the minutes of moderate PA to calculate leisure-time PA (LTPA). LTPA was stratified into none (i.e., 0 min/week), low (i.e., > 0 to < 150 min/week), and high (i.e., ≥ 150 min/weeks) [9].

Persons with the following characteristics were considered to have an indication (i.e., treatment-eligible) for pharmacotherapy: stage 2 hypertension; stage 1 hypertension with diabetes, CKD, or high CVD risk; and SBP $\geq 130 \text{ mmHg}$ with ≥ 65 years of age. Unmet treatment goals were considered when the SBP/DBP was $\geq 130/80 \text{ mmHg}$ if the age was < 65 years or when the SBP was $\geq 130 \text{ mmHg}$ if the age was ≥ 65 years among individuals currently taking antihypertensive medications [5, 6].

Based on the published literature, biologic plausibility, and data structure, the following potential factors were selected for investigation: age (only for the overall population), sex, race, cholesterol, HDL cholesterol, body weight, CKD, diabetes, LTPA, and family income to poverty ratio (Supplementary Table 1).

Statistical analysis

The background characteristics of the respondents were reported according to age. Continuous variables were described by mean and standard error (SE). Unweighted numbers and weighted percentages were used to report categorical variables. The prevalence (with 95% confidence interval [CI]) of hypertension was determined according to the background characteristics of all age groups. The proportion of persons with indications for pharmacotherapy was estimated. Then, among treatment-indicated persons, untreated persons (i.e., persons who were not receiving pharmacotherapy despite being eligible for treatment) were reported separately. Furthermore, among the people who reported that they were currently taking antihypertensive drugs, the proportion of persons who were not meeting the

treatment goals was estimated. Logistic regression analysis was then conducted to obtain crude odd ratios (CORs). Variables with predetermined significance levels ($p < 0.2$) from the CORs (Supplementary Table 1) were included in the multivariable models to obtain adjusted ORs (AORs) [22]. Adjusted models were created for all age strata and the overall study population. AORs were presented with 95% CIs and p -values. The proportion of missing data was low (Supplementary Table 2). The multistage cluster-sampling design was used to report the weighted proportions and ORs; the sample weights from the mobile examination centers were used to obtain all the estimates. Stata 14.0 (College Station, Texas, USA) was used to analyze the data [23].

Results

Table 1 describes the background characteristics of the hypertensive participants and the overall study population. The analysis included 16,103 individuals (7811 men and 8292 women) representing 223,364,258 US adults. The mean SBP, DBP, and age of the participants were 124.2 mm Hg (SE: 0.1), 70.5 mm Hg (SE: 0.1), and 49.5 years (SE: 0.1), respectively. The proportion of men and women participants was roughly equal in the overall study population; however, the proportion of females in the group of hypertensive participants increased with age. About two-thirds of the participants were non-Hispanic whites (65.6%) followed by other races/ethnicities (14.5%), non-Hispanic blacks (11.4%), and Mexican-Americans (8.5%). Among the hypertensive subjects, the proportion of individuals with high cholesterol, CKD, diabetes, and high CVD risk increased gradually with age. In contrast, the proportion of people with low HDL-cholesterol levels, obesity, and high LTPA decreased gradually among hypertensive individuals with increasing age. Approximately 63.0% of the overall people were from the top wealth category (i.e., family income to poverty ratio ≥ 2).

The overall prevalence (95% CI) of hypertension was 46.8% (45.4–48.3). The prevalence of hypertension was 17.4% (15.8–19.1), 39.2% (37.0–41.5), 62.3% (60.1–64.6), and 77.7% (75.3–79.8) among people with 20–34, 35–49, 50–64, and ≥ 65 years of age, respectively (Table 2). The prevalence increased with age regardless of characteristics. Among the races, non-Hispanic blacks had the highest prevalence of hypertension in all age groups. For individuals in the 20–34, 35–49, 50–64, and ≥ 65 year age groups, the prevalence (95% CI) of hypertension was 24.0% (21.5–26.6), 44.5% (41.2–47.9), 65.2% (61.9–68.3), and 74.5% (70.6–78.1) in men and 10.8% (9.0–12.8), 34.3% (31.7–36.9), 59.7% (55.9–63.4), and 80.1% (77.5–82.4) in women, respectively. People with high cholesterol levels,

Table 1 Background characteristics of the overall and participants classified as hypertensive stratified by age, NHANES 2011–2016

Traits	Participants classified as hypertensive by age (in years)					Overall study population (n = 16,103)
	20–34 (n = 722/4093)	35–49 (n = 1654/4024)	50–64 (n = 2789/4198)	≥65 (n = 3086/3788)	All age (n = 8039/16,103)	
SBP, Mean (SE), mm Hg	130.5 (0.4)	131.2 (0.4)	135.0 (0.3)	139.8 (0.4)	135.6 (0.2)	124.2 (0.1)
DBP, Mean (SE), mm Hg	78.9 (0.4)	81.9 (0.3)	75.9 (0.2)	67.1 (0.2)	74.2 (0.1)	70.5 (0.1)
Age (in years)						
Mean (SE)	–	–	–	–	58.0 (0.2)	49.5 (0.1)
20–34	–	–	–	–	10.2 (722)	27.4 (4093)
35–50	–	–	–	–	22.3 (1654)	26.6 (4024)
50–64	–	–	–	–	35.7 (2789)	26.8 (4198)
≥65	–	–	–	–	31.8 (3086)	19.2 (3788)
Gender						
Male	69.4 (497)	54.9 (888)	50.9 (1388)	42.2 (1455)	50.9 (4228)	48.2 (7811)
Female	30.6 (225)	45.1 (766)	49.1 (1401)	57.8 (1631)	49.1 (4023)	51.8 (8292)
Race						
Non-Hispanic White	56.2 (250)	59.0 (559)	68.7 (858)	75.9 (1465)	67.6 (3132)	65.6 (6066)
Non-Hispanic Black	17.9 (219)	16.5 (477)	14.2 (876)	9.5 (681)	13.6 (2253)	11.4 (3665)
Mexican-American	10.2 (87)	10.4 (217)	5.7 (374)	3.8 (303)	6.6 (981)	8.5 (2164)
Other races/ethnicities	15.6 (166)	14.2 (401)	11.4 (681)	10.8 (637)	12.3 (1885)	14.5 (4208)
Cholesterol level (in mg/dl)						
Normal (<200)	65.3 (434)	42.9 (702)	25.7 (731)	23.1 (750)	32.6 (2617)	45.9 (7039)
Borderline (200–239)	24.6 (158)	29.2 (441)	23.9 (628)	16.8 (454)	22.9 (1681)	24.0 (3504)
High (≥240)	10.1 (77)	27.9 (421)	50.3 (1278)	60.1 (1713)	44.5 (3489)	30.0 (4734)
High-density lipoprotein cholesterol (in mg/dl)						
Normal	57.7 (397)	61.3 (941)	68.1 (1719)	73.9 (1995)	67.4 (5052)	70.5 (10357)
Low (<40 for men and <50 for women)	42.3 (271)	38.7 (610)	31.9 (851)	26.1 (777)	32.6 (2509)	29.5 (4671)
Chronic kidney disease						
No	89.6 (635)	88.3 (1397)	81.9 (2139)	58.1 (1644)	76.5 (5815)	85.1 (12981)
Yes	10.4 (79)	11.7 (227)	18.1 (576)	41.9 (1302)	23.5 (2184)	14.9 (2814)
Diabetes mellitus status						
No	91.8 (650)	81.9 (1281)	70.6 (1773)	66.5 (1857)	74.0 (5561)	83.4 (12515)
Prediabetes	3.7 (30)	7.9 (127)	8.9 (227)	8.7 (228)	8.1 (612)	6.1 (950)
Diabetes	4.5 (31)	10.2 (202)	20.5 (670)	24.7 (866)	17.9 (1769)	10.5 (2221)
Body mass index (in kg/m ²)						
<25	20.9 (154)	14.1 (262)	19.1 (564)	24.3 (743)	19.8 (1723)	29.5 (4695)
25 to <30	23.5 (161)	32.5 (479)	31.5 (822)	36.5 (1054)	32.5 (2516)	32.8 (5038)
≥30	55.6 (401)	53.4 (880)	49.4 (1322)	39.1 (1111)	47.7 (3714)	37.8 (6013)
Leisure time physical activity (in minutes)						
No	76.6 (545)	82.0 (1392)	90.5 (2573)	93.3 (2910)	88.1 (7420)	81.9 (13689)
Some (<150)	7.2 (48)	7.1 (93)	3.5 (76)	2.8 (63)	4.5 (280)	6.1 (785)
High (≥150)	16.2 (129)	10.9 (166)	6.1 (139)	3.9 (108)	7.5 (542)	11.9 (1618)
Family income to poverty ratio						
<2	45.0 (371)	36.3 (742)	31.8 (1210)	39.5 (1478)	36.6 (3801)	36.7 (7305)
≥2	55.0 (298)	63.7 (787)	68.2 (1306)	60.5 (1270)	63.4 (3661)	63.3 (7383)
CVD risk						
<5%	93.6 (587)	78.3 (1050)	33.3 (630)	0.4 (6)	39.2 (2273)	63.0 (8033)
5 to <10%	3.2 (15)	12.1 (198)	32.0 (678)	7.7 (165)	16.7 (1056)	12.1 (1619)
10 to <20%	0.8 (6)	3.2 (50)	19.4 (520)	24.3 (605)	15.4 (1181)	8.9 (1476)
≥20%	0.7 (4)	0.3 (5)	3.0 (96)	35.9 (933)	12.7 (1038)	6.7 (1195)
History of CVD	1.8 (12)	6.1 (101)	12.3 (359)	31.7 (885)	16.0 (1357)	9.2 (1651)

Numbers are presented as weighted percentages and unweighted numbers unless otherwise specified

Numbers may not add up to total because of missing values

The numbers in the numerator and denominator in each column heading indicate the number of hypertensive people and number of the total people from that age group, respectively

CVD cardiovascular disease, DBP diastolic blood pressure, NHANES National Health and Nutrition Examination Survey, SBP systolic blood pressure, SE standard error

Table 2 Age-stratified and overall prevalence (with 95% confidence interval) of hypertension among US adults (aged ≥ 20 years) per background characteristics, NHANES 2011–2016

Characteristics	Stratification by age (in years)				Among all age groups (n=8251/16,103)
	20–34 (n=722/4093)	35–49 (n=1654/4024)	50–64 (n=2789/4198)	≥ 65 (n=3086/3788)	
Gender					
Male	24.0 (21.5–26.6)	44.5 (41.2–47.9)	65.2 (61.9–68.3)	74.5 (70.6–78.1)	49.5 (47.5–51.4)
Female	10.8 (9.0–12.8)	34.3 (31.7–36.9)	59.7 (55.9–63.4)	80.1 (77.5–82.4)	44.4 (42.7–46.1)
Race					
Non-Hispanic White	17.3 (15.0–19.8)	38.3 (35.0–41.7)	60.2 (56.9–63.4)	75.8 (73.1–78.4)	48.2 (46.3–50.1)
Non-Hispanic Black	23.7 (20.5–27.2)	53.8 (50.3–57.2)	78.0 (75.2–80.5)	89.7 (87.3–91.7)	55.7 (53.9–57.5)
Mexican-American	15.3 (12.6–18.5)	35.8 (32.0–39.8)	60.4 (56.3–64.3)	79.8 (73.4–85.0)	36.3 (33.4–39.4)
Other race/ethnicity	14.8 (12.2–17.8)	34.3 (30.9–37.8)	61.4 (57.3–65.3)	80.9 (77.3–84.1)	39.7 (37.4–42.0)
Cholesterol level (in mg/dl)					
Normal (<200)	15.0 (13.1–17.1)	33.5 (30.7–36.6)	56.4 (52.3–60.3)	73.7 (69.1–77.8)	33.3 (31.4–35.2)
Borderline (200–239)	22.8 (19.4–26.7)	37.7 (33.8–41.8)	54.2 (49.6–58.7)	71.0 (65.0–76.2)	44.6 (42.2–47.0)
High (≥ 240)	26.9 (20.7–34.2)	55.3 (50.8–59.7)	70.6 (67.3–73.8)	81.3 (79.0–83.3)	69.4 (67.2–71.5)
High-density lipoprotein cholesterol (in mg/dl)					
Normal	14.3 (12.5–16.4)	35.3 (32.3–38.5)	59.1 (56.4–61.8)	75.7 (73.1–78.2)	44.4 (42.6–46.2)
Low (<40 for men and <50 for women)	23.7 (21.4–26.2)	46.8 (43.3–50.3)	68.1 (63.9–72.0)	81.8 (77.4–85.4)	51.5 (49.7–53.2)
Chronic kidney disease					
No	16.6 (14.8–18.5)	37.5 (35.2–40.0)	59.4 (57.0–61.8)	73.1 (70.1–75.9)	42.0 (40.6–43.5)
Yes	30.4 (23.5–38.4)	58.9 (52.2–65.4)	79.5 (74.1–84.0)	84.7 (81.5–87.4)	73.8 (71.1–76.4)
Diabetes mellitus status					
No	16.5 (14.9–18.3)	36.3 (34.2–38.4)	57.7 (55.1–60.2)	74.1 (70.9–77.0)	41.1 (39.6–42.6)
Prediabetes	24.6 (15.6–36.6)	50.2 (40.5–60.0)	68.1 (60.0–75.2)	82.9 (77.0–87.5)	61.8 (57.6–65.9)
Diabetes	47.9 (33.1–63.1)	62.9 (56.0–69.2)	79.3 (72.7–84.7)	86.9 (83.4–89.8)	78.4 (75.2–81.2)
Body mass index (in kg/m²)					
<25	9.2 (7.1–11.9)	20.8 (17.6–24.5)	49.4 (45.3–53.5)	70.3 (66.3–74.0)	31.4 (29.4–33.5)
25 to <30	14.3 (11.6–17.6)	37.4 (34.4–40.5)	59.2 (55.0–63.3)	77.3 (73.2–80.9)	46.2 (44.4–48.1)
≥ 30	30.3 (27.6–33.1)	53.0 (49.7–56.2)	71.9 (69.1–74.5)	82.6 (79.3–85.5)	58.9 (57.1–60.7)
Leisure time physical activity (in minutes)					
No	18.3 (16.6–20.3)	40.9 (38.5–43.4)	64.6 (62.4–66.7)	78.5 (75.9–80.8)	50.3 (48.8–51.8)
Some (<150)	14.9 (10.8–20.3)	35.2 (26.4–45.1)	49.7 (37.5–61.9)	74.7 (59.7–85.4)	33.9 (29.3–38.9)
High (≥ 150)	15.0 (12.2–18.4)	31.3 (25.9–37.2)	45.5 (38.3–53.0)	63.5 (52.1–73.5)	29.3 (26.8–32.1)
Family income to poverty ratio					
<2	16.7 (14.7–18.9)	42.8 (39.8–45.8)	66.7 (63.7–69.5)	82.9 (80.7–84.8)	46.4 (44.5–48.4)
≥ 2	17.8 (15.2–20.7)	37.6 (34.7–40.5)	60.4 (57.5–63.2)	75.1 (72.1–78.0)	46.7 (44.7–48.8)
Risk categories ($\geq 10\%$ 10-years CVD risk or history of CVD)					
Low	16.4 (14.8–18.1)	36.1 (33.7–38.5)	53.3 (50.3–56.3)	46.6 (40.4–52.9)	33.6 (32.2–35.1)
High	29.8 (18.7–44.1)	72.4 (65.2–78.6)	83.2 (79.6–86.3)	81.4 (78.9–83.7)	80.4 (78.3–82.3)
Stages of BP levels					
Normal	67.6 (65.6–69.6)	48.3 (46.1–50.4)	25.1 (23.1–27.2)	13.2 (11.3–15.4)	40.6 (39.2–42.1)
Elevated BP	14.9 (13.5–16.5)	12.5 (11.0–14.2)	12.6 (11.0–14.3)	9.1 (7.9–10.5)	12.5 (11.6–13.5)
Stage 1 ^a	11.9 (10.6–13.3)	17.4 (16.0–19.0)	16.0 (14.4–17.8)	9.5 (8.1–11.1)	14.0 (13.1–15.0)
Stage 2 ^b	3.3 (2.7–3.9)	7.6 (6.5–8.8)	10.9 (9.6–12.4)	11.9 (10.6–13.4)	8.1 (7.4–8.9)
Take BP lowering drug	2.2 (1.8–2.8)	14.2 (12.7–15.8)	35.4 (33.0–37.9)	56.2 (53.4–59.0)	24.7 (23.3–26.1)
Overall hypertension ^c	17.4 (15.8–19.1)	39.2 (37.0–41.5)	62.3 (60.1–64.6)	77.7 (75.3–79.8)	46.8 (45.4–48.3)

^aSystolic BP/diastolic BP 130–139/80–89 mm Hg among persons who were not taking BP lowering drugs^bSystolic BP/diastolic BP $\geq 140/90$ mm Hg among persons who were not taking BP lowering drugs^cSystolic BP/diastolic BP $\geq 130/80$ mm Hg or was taking any BP lowering drugs

BP blood pressure, CVD cardiovascular disease, NHANES National Health and Nutrition Examination Survey

The numbers in the numerator and denominator in each column heading indicate the number of hypertensive people and number of the total people from that age group, respectively

low HDL-cholesterol levels, CKD, and no LTPA had the highest prevalence of hypertension in all age groups;

however, the differences within subcategories of many of these characteristics declined with increasing age. Although

the prevalence of stage 1 hypertension was similar across age groups, the prevalence of stage 2 hypertension increased progressively with age. More than one-third of people aged 50–64 years were taking BP-lowering drugs, and more than half of those aged 65 years or older were taking BP-lowering drugs, 35.4% (95% CI: 33.0–37.9) and 56.2% (95% CI: 53.4–59.0), respectively. The prevalence (95% CI) of treated individuals who did not meet their treatment goals was 58.6% (46.1–70.2), 50.4% (44.7–56.1),

51.9% (47.6–56.1), 63.1% (59.4–66.5), and 56.7 (54.1–59.3) among people with 20–34, 35–49, 50–64, ≥ 65 years of age, and the overall population, respectively.

The proportion (95% CI) of treatment-eligible individuals was 6.9% (6.1–7.8), 24.4% (22.4–26.5), 51.4% (49.0–53.8), and 77.0% (74.7–79.2) among people 20–34, 35–49, 50–64, and ≥ 65 years of age, respectively (Table 3). The characteristics that were associated with a higher prevalence of hypertension (e.g., non-Hispanic black race, high

Table 3 Age-stratified and overall proportion (with 95% confidence interval) of individuals eligible to receive antihypertensive medication with characteristics among US adults (aged ≥20 years), NHANES 2011–2016

Characteristics	Age (in years)				Among all age groups (n=6814/16,103)
	20–34 (n=299/4093)	35–49 (n=1054/4024)	50–64 (n=2388/4198)	≥65 (n=3073/3788)	
Gender					
Male	8.3 (7.1–9.7)	27.0 (24.0–30.1)	54.8 (51.4–58.2)	74.1 (70.2–77.6)	37.4 (35.5–39.3)
Female	5.4 (4.3–6.7)	22.0 (19.8–24.5)	48.1 (44.7–51.6)	79.3 (76.7–81.6)	36.5 (34.8–38.3)
Race					
Non-Hispanic White	6.5 (5.5–7.8)	23.4 (20.6–26.4)	48.9 (45.7–52.1)	75.1 (72.4–77.6)	38.6 (36.6–40.6)
Non-Hispanic Black	11.3 (9.2–13.8)	37.3 (33.6–41.3)	70.4 (67.2–73.3)	89.2 (86.5–91.4)	45.1 (43.1–47.1)
Mexican-American	5.7 (4.1–7.8)	22.6 (19.1–26.5)	46.6 (41.0–52.3)	79.8 (73.4–85.0)	25.5 (22.2–29.1)
Other races/ethnicity	5.5 (4.1–7.5)	20.0 (17.6–22.5)	50.4 (46.3–54.5)	80.6 (76.8–83.8)	29.8 (27.5–32.1)
Cholesterol level (in mg/dl)					
Normal (<200)	5.4 (4.6–6.4)	20.2 (17.7–22.9)	45.1 (40.9–49.4)	72.6 (68.0–76.7)	23.2 (21.6–25.0)
Borderline (200–239)	9.8 (7.3–13.0)	21.4 (18.1–25.1)	41.0 (36.9–45.4)	70.1 (64.2–75.5)	32.2 (29.7–34.9)
High (≥240)	15.7 (10.1–23.4)	40.1 (35.8–44.6)	61.7 (58.2–65.1)	80.8 (78.4–83.0)	62.3 (60.0–64.7)
High-density lipoprotein cholesterol (in mg/dl)					
Normal	5.3 (4.5–6.3)	20.7 (18.1–23.5)	47.6 (44.4–50.8)	74.9 (72.3–77.2)	34.9 (32.9–37.0)
Low (<40 for men and <50 for women)	10.5 (8.5–12.9)	32.4 (29.4–35.4)	59.2 (54.7–63.4)	81.7 (77.3–85.3)	41.1 (39.2–43.0)
Chronic kidney disease					
No	5.4 (4.6–6.2)	21.5 (19.5–23.7)	46.8 (44.3–49.2)	72.0 (68.8–75.1)	30.4 (29.0–32.0)
Yes	30.4 (23.5–38.4)	58.9 (52.2–65.4)	79.5 (74.1–84.0)	84.7 (81.5–87.4)	73.8 (71.1–76.4)
Diabetes mellitus status					
No	5.9 (5.2–6.7)	19.9 (18.1–21.9)	43.9 (41.1–46.7)	73.1 (69.9–76.1)	29.6 (28.1–31.2)
Prediabetes	24.6 (15.6–36.6)	50.2 (40.5–60.0)	68.1 (60.0–75.2)	82.9 (77.0–87.5)	61.8 (57.6–65.9)
Diabetes	26.9 (16.8–40.2)	56.6 (49.0–63.8)	76.2 (70.2–81.3)	86.8 (83.3–89.6)	75.2 (71.9–78.2)
Body mass index (in kg/m ²)					
<25	2.7 (1.8–4.2)	9.5 (7.4–12.2)	36.6 (32.2–41.3)	69.8 (65.8–73.6)	23.4 (21.1–25.8)
25 to < 30	4.4 (3.0–6.3)	20.5 (17.9–23.5)	47.3 (43.6–51.0)	76.5 (72.6–80.0)	35.8 (33.9–37.7)
≥30	14.1 (12.0–16.4)	37.5 (34.4–40.7)	62.7 (59.7–65.6)	81.9 (78.6–84.9)	47.9 (46.2–49.6)
Leisure time physical activity (in minutes)					
No	7.4 (6.3–8.5)	26.7 (24.3–29.2)	54.1 (51.8–56.4)	77.8 (75.2–80.2)	40.9 (39.3–42.4)
Some (<150)	3.7 (1.8–7.3)	16.7 (11.0–24.6)	37.0 (25.8–49.7)	74.7 (59.7–85.4)	20.9 (17.5–24.9)
High (≥150)	6.5 (4.8–8.7)	15.3 (11.8–19.5)	30.7 (23.4–39.2)	61.9 (50.9–71.7)	17.9 (15.8–20.2)
Family income to poverty ratio					
<2	6.7 (5.6–8.1)	27.8 (25.1–30.6)	58.7 (55.5–61.8)	82.7 (80.5–84.6)	37.5 (35.3–39.7)
≥2	6.5 (5.2–8.0)	22.7 (20.2–25.4)	48.2 (45.0–51.5)	74.2 (71.2–76.9)	36.1 (34.0–38.2)
Risk categories (≥10% 10-years CVD risk or history of CVD)					
Low	5.7 (4.9–6.6)	19.9 (18.1–21.7)	37.7 (35.1–40.4)	41.0 (34.3–48.0)	19.9 (18.9–21.0)
High	29.8 (18.7–44.1)	72.4 (65.2–78.6)	83.2 (79.6–86.3)	81.4 (78.9–83.7)	80.4 (78.3–82.3)
Overall	6.9 (6.1–7.8)	24.4 (22.4–26.5)	51.4 (49.0–53.8)	77.0 (74.7–79.2)	36.9 (35.4–38.5)

CVD Cardiovascular disease, NHANES National Health and Nutrition Examination Survey

The numbers in the numerator and denominator in each column heading indicate the number of people who were eligible to take antihypertensive medication and number of studied people, respectively

People with following characteristics were considered as treatment-eligible for hypertension: stage 2 hypertension; stage 1 hypertension with diabetes, chronic kidney disease or high CVD risk; and systolic blood pressure ≥130 mmHg with ≥65 years of age

cholesterol, CKD, diabetes, or high CVD risk) were also associated with an increased indication of antihypertensive treatment.

The percentage (95% CI) of people who had an indication for pharmacotherapy but remained untreated was 67.6% (61.0–73.5), 41.8% (37.7–46.0), 31.0% (28.2–34.0), and 27.0% (24.3–29.8) among 20–34, 35–49, 50–64, and ≥ 65 -year-old people, respectively (Table 4). In all age groups, a greater proportion of males were untreated

compared to females. Although the proportion of untreated individuals decreased with age, these proportions remained substantially high regardless of characteristics. Even with a high CVD risk, approximately one-third of the people were untreated, 30.0% (95% CI: 28.0–32.2).

Table 5 shows the proportion of individuals who were not meeting the treatment goals despite taking medicine. Regardless of characteristics or age, more than half of the individuals had unmet treatment goals, 56.7% (95% CI:

Table 4 Age-stratified and overall proportion (with 95% confidence interval) of untreated hypertensive US adults (aged ≥ 20 years) among people who have antihypertensive treatment indication per characteristics, NHANES 2011–2016

Characteristics	Age (in years)				Among all age groups (n=2146/6814)
	20–34 (n=199/299)	35–49 (n=452/1054)	50–64 (n=702/2388)	≥ 65 (n=793/3073)	
Gender					
Male	73.5 (65.5–80.2)	48.8 (44.0–53.7)	37.1 (32.7–41.7)	29.6 (26.0–33.5)	39.1 (36.4–41.8)
Female	58.3 (46.8–68.9)	33.8 (28.1–39.9)	24.4 (21.4–27.7)	25.1 (22.1–28.4)	27.5 (25.1–30.1)
Race					
Non-Hispanic Whites	67.3 (54.9–77.8)	39.0 (32.6–45.8)	30.9 (27.0–35.2)	27.0 (23.6–30.7)	31.9 (28.8–35.1)
Non-Hispanic Blacks	61.5 (53.4–69.0)	35.7 (29.8–42.0)	25.2 (21.3–29.5)	22.1 (19.4–25.0)	29.6 (27.2–32.2)
Mexican-Americans	71.8 (52.5–85.4)	52.8 (45.7–59.9)	34.9 (28.9–41.4)	30.8 (27.0–35.0)	42.6 (38.4–46.9)
Other race/ethnicity	74.5 (57.8–86.2)	53.8 (47.4–60.1)	37.8 (32.4–43.5)	29.8 (26.0–33.8)	40.4 (37.5–43.4)
Cholesterol level (in mg/dl)					
Normal (<200)	66.1 (54.6–76.0)	41.6 (36.3–47.0)	35.9 (29.4–43.0)	32.4 (28.2–36.9)	39.3 (36.3–42.4)
Borderline (200–239)	77.2 (62.1–87.5)	49.5 (39.9–59.0)	44.4 (38.6–50.4)	41.1 (34.6–47.9)	46.5 (41.7–51.4)
High (≥ 240)	52.3 (29.5–74.3)	34.0 (28.4–40.2)	21.9 (18.2–26.1)	20.6 (17.7–23.9)	23.1 (20.7–25.7)
High-density lipoprotein cholesterol (in mg/dl)					
Normal	69.9 (57.5–79.9)	43.3 (38.7–48.1)	33.9 (29.8–38.2)	28.8 (25.8–31.9)	34.5 (31.9–37.3)
Low (<40 for men and <50 for women)	63.8 (55.0–71.7)	38.7 (32.2–45.7)	25.1 (21.0–29.6)	21.9 (17.7–26.8)	30.0 (26.8–33.4)
Chronic kidney disease					
No	59.3 (50.2–67.8)	39.2 (34.5–44.0)	29.5 (26.6–32.4)	31.3 (27.4–35.4)	33.6 (31.0–36.4)
Yes	89.9 (81.6–94.7)	53.9 (44.4–63.2)	36.5 (31.3–41.9)	21.1 (18.8–23.6)	32.1 (29.8–34.5)
Diabetes mellitus status					
No	69.2 (61.0–76.3)	44.7 (40.2–49.2)	37.2 (33.1–41.4)	32.6 (29.7–35.8)	38.9 (36.4–41.4)
Prediabetes	75.3 (51.9–89.6)	47.4 (34.2–60.9)	31.9 (25.4–39.2)	15.5 (9.9–23.5)	31.7 (27.0–36.9)
Diabetes	39.9 (16.1–69.7)	23.7 (16.3–33.0)	15.7 (11.2–21.5)	18.6 (15.3–22.5)	18.3 (15.6–21.4)
Body mass index (in kg/m ²)					
<25	67.4 (50.9–80.5)	51.0 (38.1–63.8)	46.1 (37.4–55.1)	36.8 (32.3–41.6)	42.7 (37.6–48.0)
25 to < 30	73.4 (54.7–86.3)	46.5 (38.7–54.3)	34.4 (29.2–40.1)	28.1 (24.0–32.5)	34.6 (31.0–38.4)
≥ 30	66.4 (58.6–73.4)	38.3 (32.8–44.2)	24.1 (20.4–28.3)	20.7 (17.6–24.3)	29.1 (26.6–31.6)
Leisure time physical activity (in minutes)					
No	68.3 (60.7–75.0)	40.2 (36.0–44.7)	31.3 (28.3–34.5)	26.7 (24.0–29.5)	32.5 (30.2–34.8)
Some (<150)	76.3 (46.2–92.4)	55.9 (42.0–68.9)	22.8 (9.7–44.8)	33.3 (16.8–55.3)	38.8 (28.1–50.7)
High (≥ 150)	62.4 (39.0–81.1)	45.3 (31.1–60.3)	30.9 (21.8–41.8)	31.1 (18.7–47.0)	39.6 (32.5–47.2)
Family income to poverty ratio					
<2	65.9 (57.8–73.1)	65.9 (57.8–73.1)	29.8 (26.4–33.5)	24.3 (21.3–27.6)	33.3 (30.8–35.9)
≥ 2	70.4 (57.0–81.0)	70.4 (57.0–81.0)	31.5 (28.0–35.3)	28.5 (24.8–32.5)	33.2 (30.4–36.1)
Risk categories ($\geq 10\%$ 10-years CVD risk or history of CVD)					
Low	70.0 (61.4–77.4)	41.5 (37.4–45.7)	28.7 (24.0–33.9)	39.7 (27.9–52.9)	38.1 (34.7–41.6)
High	50.7 (22.9–78.2)	38.7 (28.1–50.4)	35.0 (31.2–39.0)	27.1 (24.6–29.8)	30.0 (28.0–32.2)
Overall	67.6 (61.0–73.5)	41.8 (37.7–46.0)	31.0 (28.2–34.0)	27.0 (24.3–29.8)	33.2 (30.9–35.5)

CVD Cardiovascular disease, NHANES National Health and Nutrition Examination Survey

The numbers in the numerator and denominator in each column heading indicate the number of people who were not receiving antihypertensive drugs despite having indication and the number of people who have antihypertensive treatment indication, respectively

People with following characteristics were considered as treatment-eligible for hypertension: stage 2 hypertension; stage 1 hypertension with diabetes, chronic kidney disease or high CVD risk; and systolic blood pressure ≥ 130 mmHg with ≥ 65 years of age

Table 5 Age-stratified and overall proportion (with 95% confidence interval) of US adults (aged ≥ 20 years) not meeting treatment goals among individuals currently reported taking antihypertensive medication per background characteristics, NHANES 2011–2016

Characteristics	Age (in years)				Among all age groups (n=2907/4668)
	20–34 (n=57/100)	35–49 (n=335/602)	50–64 (n=993/1686)	≥ 65 (n=1522/2280)	
Gender					
Male	68.3 (44.4–85.3)	56.2 (46.8–65.2)	52.4 (47.3–57.4)	57.0 (52.9–60.9)	55.3 (52.0–58.5)
Female	48.9 (31.4–66.7)	45.2 (38.2–52.5)	51.5 (45.9–57.0)	67.3 (62.4–71.8)	57.9 (54.6–61.0)
Race					
Non-Hispanic White	59.6 (38.8–77.4)	44.4 (36.1–53.1)	48.2 (42.5–53.8)	61.7 (57.3–66.0)	54.3 (51.1–57.5)
Non-Hispanic Black	61.6 (49.1–72.8)	61.7 (56.1–67.0)	63.6 (59.4–67.6)	69.5 (65.6–73.1)	64.9 (61.9–67.8)
Mexican-American	60.6 (18.3–91.4)	54.9 (42.9–66.4)	55.2 (49.0–61.3)	64.2 (56.4–71.4)	58.2 (54.1–62.2)
Other race/ethnicity	46.1 (21.6–72.6)	59.2 (49.4–68.3)	55.8 (48.2–63.2)	66.0 (59.8–71.6)	60.5 (55.8–65.0)
Cholesterol level (in mg/dl)					
Normal (<200)	61.8 (38.8–80.4)	49.4 (39.9–58.9)	50.8 (43.7–57.9)	64.4 (58.0–70.3)	55.9 (51.4–60.3)
Borderline (200–239)	58.6 (22.6–87.3)	51.9 (40.2–63.3)	57.0 (45.5–66.8)	66.3 (56.7–74.6)	59.2 (53.7–64.5)
High (≥ 240)	51.7 (26.3–76.2)	49.7 (38.9–60.6)	49.9 (44.6–55.2)	61.5 (57.5–65.3)	55.6 (52.1–59.1)
High-density lipoprotein cholesterol (in mg/dl)					
Normal	59.2 (41.8–74.6)	50.6 (42.5–58.7)	54.1 (49.3–59.0)	63.2 (58.7–67.5)	58.1 (55.1–61.1)
Low (<40 for men and <50 for women)	58.9 (36.3–78.3)	49.3 (41.5–57.1)	46.2 (39.5–53.1)	60.8 (53.3–67.8)	52.5 (48.0–56.9)
Chronic kidney disease					
No	58.8 (44.1–72.1)	49.6 (43.3–56.0)	50.4 (45.7–55.1)	60.3 (55.9–64.5)	53.9 (50.7–57.0)
Yes	56.7 (31.6–78.8)	55.0 (43.9–65.6)	56.7 (48.3–64.7)	66.3 (60.9–71.2)	62.9 (58.9–66.7)
Diabetes mellitus status					
No	55.5 (38.8–71.1)	50.2 (43.8–56.6)	54.1 (47.3–60.7)	62.1 (57.8–66.1)	56.9 (53.3–60.4)
Prediabetes	57.4 (25.1–84.5)	48.0 (31.9–64.5)	49.4 (38.4–60.5)	61.5 (50.7–71.2)	54.4 (46.7–61.9)
Diabetes	72.5 (49.9–87.5)	52.1 (40.2–63.8)	47.1 (40.3–54.0)	64.7 (58.4–70.5)	55.9 (51.4–60.4)
Body mass index (in kg/m²)					
<25	32.2 (3.6–85.7)	43.3 (28.9–58.9)	53.9 (43.0–64.4)	72.6 (65.7–78.5)	63.1 (57.1–68.7)
25 to <30	51.9 (29.9–73.2)	53.8 (43.2–64.0)	48.2 (40.4–56.0)	61.4 (56.5–66.1)	55.6 (51.3–59.8)
≥ 30	67.9 (51.7–80.7)	49.2 (42.0–56.5)	52.9 (48.4–57.4)	60.0 (54.3–65.4)	55.2 (52.4–58.0)
Leisure time physical activity (in minutes)					
No	62.3 (46.4–75.8)	50.9 (45.1–56.7)	52.1 (47.7–56.6)	63.4 (59.7–66.9)	57.2 (54.8–59.6)
Some (<150) ³	–	45.0 (17.1–76.5)	47.9 (26.7–69.8)	56.6 (33.9–76.9)	51.8 (38.6–64.7)
High (≥ 150)	38.7 (19.3–62.4)	47.7 (28.8–67.3)	50.6 (32.9–68.1)	59.9 (44.7–73.4)	51.5 (42.8–60.2)
Family income to poverty ratio					
<2	56.1 (36.6–74.0)	45.6 (38.6–52.7)	53.3 (47.8–58.8)	66.4 (62.6–70.0)	58.5 (55.5–61.5)
≥ 2	67.0 (47.3–82.1)	52.6 (44.9–60.1)	50.0 (44.7–55.3)	58.6 (52.4–64.5)	54.2 (50.5–57.9)
Risk categories ($\geq 10\%$ 10-years CVD risk or history of CVD)					
Low	55.2 (36.5–72.5)	46.7 (39.6–54.0)	39.8 (34.0–46.0)	33.6 (20.4–49.9)	42.4 (37.7–47.2)
High	52.9 (21.0–82.7)	64.8 (53.6–74.6)	63.7 (57.7–69.2)	63.2 (59.3–66.9)	63.3 (60.1–66.4)
Overall	58.6 (46.1–70.2)	50.4 (44.7–56.1)	51.9 (47.6–56.1)	63.1 (59.4–66.5)	56.7 (54.1–59.3)

CVD cardiovascular disease

The numbers in the numerator and denominator in each column heading indicate the number of people not meeting treatment goals among individuals currently reported taking antihypertensive medication and number of people who were taking antihypertensive drugs, respectively

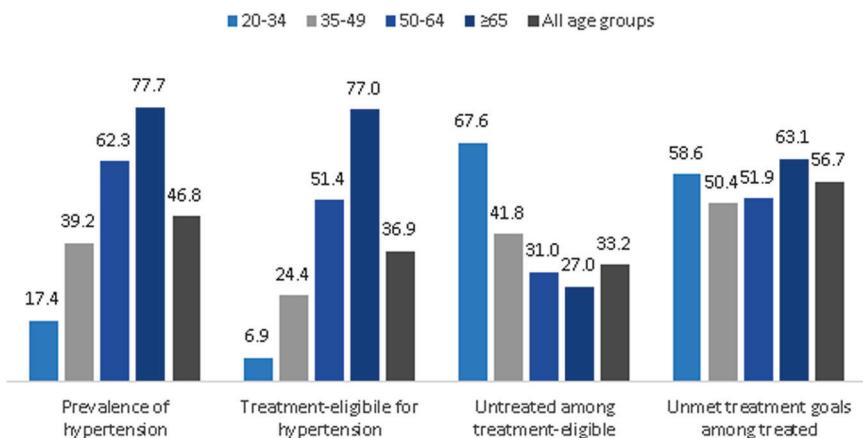
People with following characteristics were considered as unmet treatment goals for hypertension: systolic/diastolic blood pressure $\geq 130/80$ mm Hg among individuals taking any BP lowering drugs (age groups <65 years) or the systolic blood pressure ≥ 130 mm Hg (age groups ≥ 65 years)

Numbers too low to calculate proportion and 95% confidence interval for younger people

54.2–59.3). Although males had higher unmet goals before the age of 65 years, the proportion was higher among females after that age: 67.3% (95%: 62.4–71.8) and 57.0% (95% CI: 52.9–60.9), respectively. Non-Hispanic blacks had the highest proportion of people with unmet needs in all age strata. Despite the higher prevalence of hypertension among people with elevated cholesterol levels, low HDL, and CKD, these groups had a lower proportion of people

with unmet treatment goals. Excluding the youngest (i.e., 20–34 years) age group, people with higher CVD risk had a greater proportion of people with unmet goals. Figure 1 summarizes all four studied proportions according to age. With an overall awareness of 63.7% (95% CI: 61.9–65.6), approximately 31.0% (95% CI: 27.6–34.6), 52.7% (95% CI: 48.9–56.5), 67.3% (95% CI: 64.7–69.8), and 78.0% (95% CI: 75.4–80.4) of people in the 20–34, 35–49, 50–64,

Fig. 1 Prevalence of individuals with hypertension, individuals who are eligible for hypertension treatment, individuals who are untreated among the treatment-eligible group, and individuals with unmet treatment goals among the participants who reported taking antihypertensive medication by age, National Health and Nutrition Examination Survey 2011–2016



and ≥ 65 years of age groups did not meet their treatment goals, respectively (Supplementary Table 3). Some of the characteristics had low awareness levels in all age groups.

In the crude analysis, most of the factors were significantly associated with hypertension in all age groups, including in the overall population (Supplementary Table 1). As Table 6 shows, the odds of hypertension increased progressively with age for the overall population. The highest AOR was 10.7 (95% CI: 9.0–12.8) among people with ≥ 65 years of age. The overall AOR of hypertension was lower among women, 0.6 (95% CI: 0.6–0.7) compared with men. While the odds of hypertension were lower for women aged < 65 years, the AOR of hypertension was higher for women aged ≥ 65 years, 1.3 (95% CI: 1.0–1.7). In all age strata, non-Hispanic blacks had higher odds of hypertension than non-Hispanic whites. Although borderline elevated cholesterol was a significant factor in the youngest age group and the overall population, it was not associated with hypertension in all age groups. Moreover, a low HDL-cholesterol level was associated with a higher odds of hypertension only among the 20–34 years age group (AOR: 1.4, 95% CI: 1.2–1.7). Diabetes, CKD, and elevated BMI were associated with higher odds of hypertension in all age groups. Higher LTPA (i.e., ≥ 150 min) was associated with lower odds of hypertension. Although a high family income to poverty ratio was associated with lower odds of hypertension among people aged ≥ 65 years, it was not significant in other age groups or the overall population.

Discussion

Using a large nationally representative sample, this study stratified prevalence, treatment status, and associated factors of hypertension among US adults according to age based on the application of the 2017 ACC/AHA guideline. After stratification, the findings indicate that roughly ‘1 in 5’, ‘2 in

5’, ‘3 in 5’, and ‘4 in 5’ adults in the 20–34, 35–49, 50–64, and ≥ 65 year age groups, including approximately half of the overall population, could have hypertension. A substantial proportion of these individuals could either have an indication for pharmacotherapy but not be taking medication or be receiving treatment but not meeting treatment goals. Sex, race, high cholesterol, low HDL, CKD, diabetes, and LTPA were associated with higher prevalence, treatment indication, and odds of hypertension. These are known risk factors for hypertension [5, 6, 8, 9]. This study reconfirmed the significance of these known factors after stratifying by age.

The prevalence of hypertension observed in this study is in agreement with the past research by Muntner et al. that also estimated the prevalence in the same age ranges using the 2011–2014 NHANES datasets [5]. Unlike prior studies, this study reported the proportion of individuals who require pharmacotherapy, have higher CVD risks, were untreated despite having a treatment indication, and have unmet treatment goals, as well as associated factors according to age and among the overall population on a wide range of sociodemographic and clinical characteristics using the 2017 ACC/AHA guideline.

Similar to previous studies, in all age strata, non-Hispanic black individuals had a higher prevalence, treatment indication, and odds of hypertension than their non-Hispanic white counterparts [5, 10, 24, 25]. Although Mexican-American individuals had an overall lower prevalence of hypertension, including those in the age groups younger than 64 years, the prevalence was higher after that age. Africans living in Africa have a lower prevalence of hypertension than the global prevalence; however, African-Americans in the US consistently have a higher prevalence [26–28]. Despite similarities in genetic characteristics, the substantial socioeconomic differences between these two regions of the world could be responsible for this discrepancy [28]. The complications of hypertension are also more severe among African-Americans [10, 26]. Differences in awareness, lifestyle, and socioeconomic status

Table 6 Age-stratified and overall adjusted odds ratio (with 95% confidence interval) for the association of hypertension with selected factors among US population aged 20 years or older, NHANES 2011–2016

Characteristics	According to age (in years)				Among all age groups (n=13,216)
	20–34 (n=3534)	35–49 (n=3449)	50–64 (n=3234)	≥65 (n=2999)	
Age (in years)					
20–34	–	–	–	–	Ref.
35–49	–	–	–	–	2.7*** (2.3,3.1)
50–64	–	–	–	–	5.6*** (4.7,6.5)
≥65	–	–	–	–	10.7*** (9.0,12.8)
Gender					
Male	Ref.	Ref.	Ref.	Ref.	Ref.
Female	0.3*** (0.2,0.4)	0.6*** (0.5,0.8)	0.7* (0.6,1.0)	1.3* (1.0,1.7)	0.6*** (0.6,0.7)
Race					
Non-Hispanic White	Ref.	Ref.	Ref.	Ref.	Ref.
Non-Hispanic Black	1.6** (1.2,2.2)	1.8*** (1.4,2.3)	2.1*** (1.6,2.8)	2.2*** (1.6,3.0)	1.8*** (1.6,2.1)
Mexican-American	0.7** (0.5,0.9)	0.7** (0.5,0.9)	0.8* (0.6,1.0)	1.1 (0.7,1.7)	0.8*** (0.7,0.9)
Other races/ethnicities	0.8 (0.6,1.2)	0.8 (0.7,1.0)	1.0 (0.8,1.4)	1.2 (0.9,1.6)	1.0 (0.8,1.1)
Cholesterol level (in mg/dl)					
Normal (<200)	Ref.	Ref.	Ref.	Ref.	Ref.
Borderline (200–239)	1.4* (1.0,1.8)	1.1 (0.9,1.3)	1.1 (0.8,1.4)	1.0 (0.8,1.4)	1.2* (1.0,1.3)
High (≥240)	1.7* (1.1,2.6)	2.1*** (1.7,2.7)	1.7*** (1.3,2.1)	1.5** (1.1,1.9)	1.8*** (1.6,2.1)
High density lipoprotein cholesterol (in mg/dl)					
Normal	Ref.	Ref.	Ref.	Ref.	Ref.
Low (<40 for men and < 50 for women)	1.4*** (1.2,1.7)	1.2 (1.0,1.5)	1.1 (0.8,1.3)	1.0 (0.7,1.5)	1.2** (1.0,1.4)
Chronic kidney disease					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Yes	2.3*** (1.5,3.6)	2.0*** (1.4,2.7)	2.3*** (1.7,3.2)	1.8*** (1.3,2.5)	2.0*** (1.7,2.4)
Diabetes					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Prediabetes	1.6 (1.0,2.5)	1.3 (0.9,2.0)	1.3 (0.9,2.0)	1.5 (1.0,2.3)	1.4** (1.1,1.7)
Diabetes	3.5** (1.6,7.7)	1.6** (1.1,2.2)	1.6* (1.0,2.5)	1.6* (1.1,2.4)	1.6*** (1.3,2.0)
Body mass index (in kg/m²)					
<25	Ref.	Ref.	Ref.	Ref.	Ref.
25 to <30	1.5* (1.1,2.1)	1.9*** (1.4,2.4)	1.4* (1.1,1.7)	1.4 (1.0,1.9)	1.5*** (1.3,1.7)
≥30	4.2*** (2.9,5.9)	3.2*** (2.4,4.3)	2.1*** (1.6,2.7)	1.6** (1.1,2.2)	2.6*** (2.2,3.0)
Leisure time physical activity (in minutes)					
No	Ref.	Ref.	Ref.	Ref.	Ref.
Some (<150)	0.8 (0.6,1.2)	1.0 (0.6,1.4)	0.6 (0.4,1.1)	1.3 (0.5,3.1)	0.9 (0.7,1.1)
High (≥150)	0.8 (0.5,1.1)	0.8 (0.5,1.0)	0.5** (0.4,0.7)	0.6 (0.3,1.1)	0.7*** (0.6,0.8)
Family income to poverty ratio					
<2	Ref.	Ref.	Ref.	Ref.	Ref.
≥2	1.2 (0.9,1.6)	0.9 (0.7,1.1)	0.9 (0.7,1.1)	0.8* (0.6,1.0)	0.9 (0.8, 1.0)

*p < 0.05, **p < 0.01, ***p < 0.001

NHANES National Health and Nutrition Examination Survey

Adjusted for all variables in the column

The numbers in the numerator and denominator in each column heading indicate the number of hypertensive people and number of the total people from that age group, respectively

between races could be responsible for this difference [9, 12]. Considering treatment status, a greater proportion of African-Americans than of individuals of other races

were receiving treatment; however, the proportion of individuals not meeting treatment goals was also higher among African-Americans in all age strata.

Elevated BMI, diabetes, high cholesterol, low HDL, and CKD were significantly associated with hypertension. All of these conditions correlate with one another [29]. The complex mechanisms by which these factors interact are only partially understood and are beyond the scope of this discussion; nevertheless, preventing and treating these comorbid conditions could minimize future disease risks and complications not only from hypertension but also from the conditions themselves [10, 26, 28]. These comorbidities are also of clinical and public health significance, and the prevalence of these conditions increases with increasing age [6, 29].

Although the proportion of individuals who require pharmacotherapy or who were taking antihypertensive medication increased along with the overall prevalence, a substantial proportion of these individuals remained untreated or were not meeting the treatment goals. Young adults (i.e., ages 20–34 years) need more awareness and preventive and treatment measures considering that they had the highest proportion of untreated individuals or people with less awareness (Supplementary Table 3). Even among the treated individuals, a large proportion did not meet their treatment goals. Young adults also had slightly different correlates than other people. In addition to the 17.4% prevalence of hypertension in the youngest age group, ~15% of them also had elevated BP (i.e., SBP: 120–129 mmHg), which was the highest of all the age groups. Hypertension and other correlated conditions are more likely to develop in later stages of life if preventive measures are not taken. At least, preventive measures may slow down the progression to hypertension and other associated conditions [6].

It is recommended that all individuals with hypertension or elevated BP adhere to lifestyle and dietary recommendations, regardless of CVD risk [5, 6]. Overall, a higher level of LTPA had an inverse association with hypertension. Among hypertensive subjects from each age stratum, a small proportion of people was engaged in ≥150 min of LTPA and that proportion declined with age (Table 1). Increasing LTPA is also essential for the prevention of the aforementioned conditions, including overweight/obesity, dyslipidemia, and diabetes [9, 27, 28, 30]. In addition to lifestyle measures, maintaining ideal BP levels using pharmacotherapy among treatment-indicated people is especially important for reducing CVD, kidney, and other disease burdens. Those who are untreated or have unmet treatment goals with characteristics such as CKD or high CVD risks are more vulnerable to the adverse consequences of hypertension. Connecting treatment-indicated hypertensive people to the proper therapy is essential [6, 10, 11]. Furthermore, if the participants of the current study ever received an evaluation, were treated and evaluated according to prior guidelines that differ from the 2017 ACC/AHA guideline [6, 31]. Therefore, reevaluating and regularly

monitoring the BP of treated individuals to ensure that they are being treated appropriately is important.

The strengths of the study include the generalizability of the results as NHANES yields large nationally representative samples that allow for adequate subgroup analysis. NHANES follows standardized validated protocols. The proportions were obtained after applying sample weights with appropriate statistical procedures.

Limitations

Although the 2017 ACC/AHA recommends measuring BP on multiple occasions, NHANES measures BP on a single day [5, 6]; some hypertensive subjects could have white coat hypertension [32, 33]. Furthermore, due to the cross-sectional nature of the datasets, the observed associations may not be causal. However, all these characteristics were confirmed by earlier cohort studies [6]. As the study participants (NHANES 2011–2016) were evaluated or treated based on previous guidelines, calculating the prevalence of people with unmet treatment goals or people who are untreated despite treatment eligibility may cause some overestimation.

Conclusion

Implementing the new guideline revealed that a large proportion of US adults across all age groups were hypertensive and at risk for complications resulting from hypertension. The adoption of preventive lifestyle and dietary measures from a young age may prevent and reduce the burden of hypertension and other correlated conditions. Ensuring adequate treatment from a younger age is also important because a large proportion of the individuals in this study were untreated despite being eligible or were not meeting their treatment goals. Addressing characteristics associated with a higher prevalence of hypertension and ensuring adequate treatment for people with indications for pharmacotherapy, particularly from a younger age, are essential. Regardless of age, reevaluation and regular BP monitoring of individuals with unmet treatment goals or who are being treated with pharmacotherapy are important.

Data availability

The datasets are publicly available at the Centers for Disease Control and Prevention's website. Dr. Kibria has full access to the data and takes responsibility for the integrity of the data analysis.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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