

Hypertension in Early-Stage Kidney Disease: An Update From the Kidney Early Evaluation Program (KEEP)

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Background: Chronic kidney disease (CKD) is a worldwide public health problem. Systolic blood pressure as an associated feature of CKD has not been fully explored in community volunteer and nationally representative samples of the US population.

Methods: This cross-sectional analysis evaluated hypertension and early-stage CKD in participants in the Kidney Early Evaluation Program (KEEP), a voluntary community-based health screening program administered by the National Kidney Foundation, and the National Health and Nutrition Examination Survey (NHANES) data to assess similarities and differences between these populations. Participants in both databases were 18 years or older.

Results: The KEEP database included 88,559 participants and the NHANES included 20,095. Hypertension prevalence was greater in KEEP (69.6%) than NHANES (38.1%; $P < 0.001$). Compared with NHANES participants, KEEP participants had greater rates of obesity (79.5% versus 51.5%; $P < 0.001$) and diabetes (28.0% versus 8.9%; $P < 0.001$). In participants with diabetes, KEEP had slightly greater rates of prevalent hypertension (88.5% versus 85.7%; $P = 0.03$). In participants with hypertension, CKD stages 3 and 4 were more prevalent in KEEP than NHANES (79.1% versus 69.3%; $P < 0.001$). Rates of CKD stages 3 and 4 were greater in KEEP than NHANES for the following subgroups: African Americans (72.4% versus 57.4%; $P < 0.001$), smokers (69.1% versus 55.6%; $P = 0.002$), and participants with hypercholesterolemia (80.2% versus 71.9%; $P < 0.001$).

Conclusions: In the volunteer KEEP population, rates of hypertension and CKD were greater than in NHANES, most prominently in African Americans and participants with increased cardiovascular risk. *Am J Kidney Dis* 53(S4):S22-S31. © 2009 by the National Kidney Foundation, Inc.

INDEX WORDS: Chronic kidney disease; hypertension; systolic blood pressure.

The number of adults with hypertension has more than doubled in the last 20 years, and hypertension prevalence is likely to far exceed predictions for 2025.¹ Overall awareness and treatment of hypertension, assessed by means of blood pressure control, in National Health and Nutrition Examination Survey (NHANES) participants increased from 29% in 1999 to 2000 to 37% in 2003 to 2004.² NHANES data show that the age-adjusted hypertension preva-

lence in the US population increased from more than 60 million adults in 2000^{3,4} to 72 million in 2004.³⁻⁵ Increases in prevalence translate into increases in cost of hypertension treatment (estimated in 2006 to exceed \$55 billion⁶) and comorbid conditions.

Chronic kidney disease (CKD) is a worldwide public-health problem.⁷ The prevalence of CKD stages 3 to 5 in the United States has grown by 40% during the past decade to 14.8%. An estimated 8 million people have an estimated glomerular filtration rate (eGFR) less than 60 mL/min/1.73 m² in the United States.⁸ Because CKD is an independent risk factor for cardiovascular death, increases in CKD prevalence are consequential.⁹

The Kidney Early Evaluation Program (KEEP), a National Kidney Foundation screening program to help promote CKD awareness, targets individuals 18 years or older with diabetes or hypertension or otherwise at high risk of CKD. KEEP collects completed participant surveys regarding past medical events and measures blood pressure and laboratory values. Hypertension prevalence at various CKD stages has been compared between KEEP and NHANES.¹⁰ Preva-

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lences of cardiovascular risk¹¹ and anemia¹² and trends in mineral metabolism¹³ also have been compared.

The early decrease in kidney function (CKD stage 1 or 2) caused by increased blood pressure has not been extensively investigated in prospective studies, with only 2 underpowered studies available to date.^{14,15} Systolic blood pressure is the most clinically useful predictor of CKD in people older than 50 years,¹⁶ but this has not been validated in appropriately powered trials with CKD outcomes.¹⁷

Given this background, we evaluated the KEEP and NHANES databases to examine whether systolic blood pressure greater than 130 mm Hg was independently associated with CKD stage. The hypothesis is that rates and severity of hypertension would differ between individuals with CKD who volunteered for CKD screening (KEEP) and those who volunteered to participate in a representative sample assessed for general health status (NHANES).

METHODS

KEEP Participants

KEEP is a free community-based health screening program that targets populations 18 years and older with a history of diabetes or hypertension or a first-order relative with diabetes, hypertension, or kidney disease. The KEEP database was fully described in the 2007 KEEP Annual Data Report.¹⁸ Officially launched nationwide in August 2000 and now in its ninth year, KEEP has screened more than 115,000 participants from 49 states and the District of Columbia.

In this study, we included only eligible KEEP participants from August 2000 through December 31, 2007. Our KEEP study cohort includes 88,559 eligible participants with non-missing values for age and blood pressure.

NHANES (1999 to 2006)

Because NHANES participants are not specifically recruited based on CKD risk factors, they provide a comparison for KEEP with respect to hypertension, CKD, and the interrelationships between these variables according to population. To make comparisons with KEEP data, NHANES 1999 to 2006 data were restricted to participants 18 years or older ($n = 22,624$). For all analyses using smoking status, self-reported cardiovascular disease, or self-reported high cholesterol level, the NHANES study population was limited to participants 20 years or older ($n = 20,311$). A complete description of the NHANES database is available in the 2007 KEEP Annual Data Report.¹⁸

Definitions

In KEEP and NHANES, we applied a common definition for hypertension: self-reported hypertension or increased blood pressure,¹⁹ defined as systolic blood pressure of 130 mm Hg or greater or diastolic blood pressure of 80 mm Hg or greater for participants with a history of diabetes or CKD and systolic blood pressure of 140 mm Hg or greater or diastolic blood pressure of 90 mm Hg or greater otherwise. For analysis purposes, we also categorized participants into 4 groups based on systolic blood pressure measurements less than 130, 130 to 139, 140 to 149, and 150 mm Hg or greater.

In KEEP and NHANES, CKD was defined as eGFR less than 60 mL/min/1.73 m² or albumin-creatinine ratio of 30 mg/g or greater. GFR was estimated using the isotope dilution mass spectrometry–traceable 4-variable Modification of Diet in Renal Disease (MDRD) Study equation,²⁰ and serum creatinine was calibrated to the Cleveland Clinic Research Laboratory.²¹ CKD stage 2 was defined as eGFR of 60 to 89 mL/min/1.73 m² and albumin-creatinine ratio of 30 mg/g or greater, and stages 3 and 4, as eGFR of 15 to 59 mL/min/1.73 m². In NHANES, GFR is estimated based on a standardized creatinine value for NHANES 1999-2000, 2001-2002, 2003-2004, and 2005-2006 separately, based on National Center for Health Statistics recommendations. The formula used to estimate GFR is $(\text{GFR} = 175 \cdot \text{standardized serum creatinine}^{-1.154} \cdot \text{age}^{-0.203} \cdot 1.212 [\text{African Americans}] \cdot 0.742 [\text{women}])$.²⁰

Other health status variables in KEEP and NHANES include self-reported diabetes, self-reported cardiovascular disease, obesity, and self-reported high cholesterol level. In KEEP, self-reported diabetes included self-reported history of diabetes or use of medication for diabetes. Obesity was defined as body mass index (BMI) of 30 kg/m² or greater. Self-reported cardiovascular disease included history of heart attack, heart angioplasty, bypass surgery, heart failure, abnormal heart rhythm, or stroke. Self-reported high cholesterol level was defined as a participant being told that he or she had a high cholesterol level. NHANES definitions for these conditions were the same as the KEEP definitions, except that self-reported diabetes was defined as self-reported history of diabetes and cardiovascular disease was defined as self-reported history of coronary heart disease, angina/angina pectoris, heart attack, congestive heart failure, or stroke. Race/ethnicity groups in NHANES are non-Hispanic white, non-Hispanic black, and other.

Statistical Analysis

Hypertension prevalence and systolic blood pressure status were calculated based on demographic characteristics, health conditions, eGFR, and albuminuria. To obtain national estimates of each statistic in NHANES, sampling weights and survey design were implemented by using SUDAAN (Research Triangle Institute, Research Triangle Park, NC).²² The *t*-test was used to calculate the *P* value for the comparison of hypertension prevalence between the KEEP and NHANES populations. The prevalence of CKD stages 3 and 4 in each systolic blood pressure group was also calculated for demographic characteristics and health conditions for the cohort with CKD stages 2 to 4.

Table 1. Prevalence of Hypertensive Status by Participant Characteristics

Characteristics	KEEP						NHANES*						P‡
	All	Hypertension†	Systolic Blood Pressure (mm Hg)				All	Hypertension†	Systolic Blood Pressure (mm Hg)				
			<130	130-139	140-149	≥150			<130	130-139	140-149	≥150	
All	88,559	61,609 (69.6)	43.8	20.5	15.9	19.8	20,095	8,537 (38.1)	71	13.3	7	8.7	<0.001
Age (y)													
18-30	6,867	2,072 (30.2)	73.2	16.4	6.7	3.8	5,921	600 (11.2)	91	6.6	2.1	0.3	
31-45	19,063	9,428 (49.5)	60.8	19.3	11	8.8	4,643	1,176 (24.2)	84.6	9.8	3.7	1.9	
46-60	31,008	22,310 (72.0)	42.4	21.3	16.6	19.6	3,756	1,950 (48.0)	63.2	18.4	8.9	9.4	
61-75	23,824	20,723 (87.0)	29.3	21.6	20.3	28.7	3,730	2,903 (73.3)	41.2	21.1	14.9	22.8	
>75	7,797	7,076 (90.7)	25.8	20.2	19.4	34.6	2,045	1,908 (84.6)	29.4	17.1	15.2	38.3	
Sex													
Men	28,035	20,571 (73.4)	38.4	22.8	17.6	21.2	9,662	4,113 (37.7)	70.2	15.9	7.4	6.4	
Women	60,459	40,993 (67.8)	46.3	19.4	15.1	19.2	10,433	4,424 (38.4)	71.8	10.8	6.5	10.8	
Race													
White	41,336	29,540 (71.5)	42.5	21	16.3	20.2	9,689	4,451 (38.9)	70.7	13.5	7.2	8.7	
African American	29,165	21,207 (72.7)	39.7	20.4	17	22.9	4,239	2,048 (46.4)	65	14.8	8.2	12	<0.001
Other	16,375	9,894 (60.4)	53.4	19.7	13.2	13.7	6,167	2,038 (29.1)	76.3	11.6	5.3	6.7	
Hispanic													
Yes	11,024	6,426 (58.3)	53.5	19.2	12.4	14.9	5,525	1,815 (27.4)	78.1	10.5	5.1	6.4	
No	77,535	55,183 (71.2)	42.4	20.7	16.4	20.5	14,570	6,722 (39.6)	70	13.7	7.3	9.1	
Education													
<High school	13,562	10,398 (76.7)	38.4	20.2	16.5	25	6,590	3,129 (45.5)	64.1	14.1	8.5	13.4	
≥High school	73,593	50,220 (68.2)	44.8	20.5	15.8	18.9	13,472	5,377 (36.2)	72.8	13.1	6.6	7.5	
Current smoker	9,832	6,160 (62.7)	50.4	20.2	13.5	15.9	3,916	1,489 (31.9)	75.7	12.4	6.2	5.7	<0.001
Body mass index ≥ 30 kg/m ²	38,648	30,742 (79.5)	35.6	22.4	18.4	23.6	6,186	3,228 (51.5)	64.3	16.9	9	9.8	<0.001
Diabetes§	24,839	21,985 (88.5)	36.0	21.1	17.9	25	1,784	1,594 (85.7)	48.2	20.3	13.2	18.3	0.03
Cardiovascular disease§	18,861	15,658 (83.0)	37.9	20.8	17.2	24.1	2,031	1,848 (78.0)	48.2	17	13	21.8	<0.001
High cholesterol§	10,634	8,795 (82.7)	39.3	23.2	18.1	19.5	4,873	3,374 (60.1)	58.5	17.1	10.8	13.6	<0.001
eGFR (mL/min/1.73 m ²)													
<30	782	754 (96.4)	28.3	18.2	18	35.5	144	149 (98.2)	32.8	12.8	16.7	37.7	0.2
30-<40	1,625	1,543 (95.0)	31.7	19.7	18.1	30.5	217	200 (91.7)	39.8	14.4	12.9	33	0.2
40-<50	3,796	3,491 (92.0)	33.8	21.8	18	26.4	483	434 (89.7)	39.2	23.6	12.8	24.5	0.1
50-<60	7,786	6,836 (87.8)	36.3	20.9	18	24.8	926	797 (84.6)	44.2	17.5	13.9	24.3	0.06
≥60	69,994	46,039 (65.8)	45.4	20.6	15.5	18.6	17,164	6,068 (33.6)	73.7	12.9	6.3	7.1	
Albumin-creatinine ratio (mg/g)													
<30	69,314	46,611 (67.3)	45.9	21	15.6	17.5	17,328	6,052 (33.9)	73.7	13.1	6.5	6.7	
30-300	8,149	7,167 (88.0)	32.1	18.6	17.6	31.7	1,967	1,418 (75.1)	49	15.2	10.7	25.1	<0.001
>300	1,049	1,001 (95.4)	20.1	15.7	17.4	46.8	383	356 (91.9)	29.7	15.2	15	40.2	0.1

Note: Conversion factor for eGFR in mL/s/1.73 m², ×0.01667.

Abbreviations: eGFR, estimated glomerular filtration rate; KEEP, Kidney Early Evaluation Program; NHANES, National Health and Nutrition Examination Survey.

*All analyses related to smoking status, self-reported cardiovascular disease, and self-reported high cholesterol level using NHANES data are limited to participants 20 years and older. Race in NHANES: non-Hispanic white, non-Hispanic black, and other.

†Defined as self-reported hypertension or increased blood pressure (Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure).

‡Comparing hypertension, KEEP versus NHANES.

§Self reported.

||Estimate is not reliable because (SD/percentage difference) is greater than 0.30.

Multivariate logistic regressions were used to show predictors for measured hypertension in KEEP participants who self-reported no hypertension and predictors for meeting target blood pressure in KEEP participants who self-reported hypertension. Predictors included age, sex, race, smoking status, self-reported diabetes, family history of diabetes or hypertension, obesity, and CKD.

RESULTS

Overall, 88,559 KEEP participants were evaluated for hypertensive status versus 20,095

NHANES participants (Table 1). Greater proportions of KEEP participants than NHANES participants had hypertension (69.6% versus 38.1%; $P < 0.001$) and diabetes (28.0% versus 8.9%; $P < 0.001$). Hypertension prevalence in African Americans was greater in KEEP than in NHANES (72.7% versus 46.4%; $P < 0.001$). Other significant differences between databases included a greater hypertension prevalence in obese KEEP participants (79.5% versus 51.5% in NHANES;

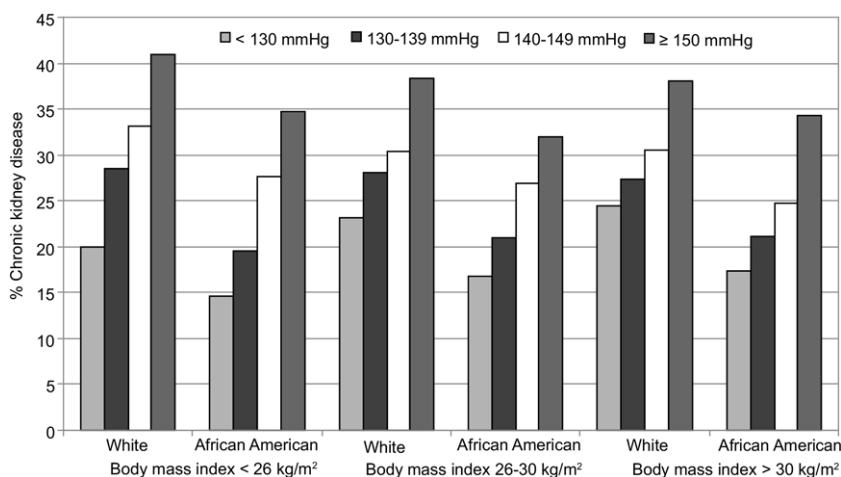


Figure 1. Percentage of KEEP participants with CKD, stratified by African American or white race, systolic blood pressure, and body mass index.

$P < 0.001$) and self-reported diabetic KEEP participants (88.5% versus 85.7% in NHANES; $P = 0.03$). The KEEP population included a greater proportion of current smokers (62.7% versus 31.9% in NHANES; $P < 0.001$) and people with high cholesterol levels (82.7% versus 60.1%; $P < 0.001$). More KEEP than NHANES participants with microalbuminuria had hypertension (88.0% versus 75.1%; $P < 0.001$), and in the higher deciles of systolic blood pressure, albuminuria and microalbuminuria were more prevalent in KEEP than in NHANES participants.

In KEEP, CKD prevalence was greater with greater systolic blood pressure (Fig 1), and CKD stages 3 and 4 prevalence was greater with greater BMI (Fig 2). Relatively more white than African American KEEP participants had a greater sys-

tolic blood pressure regardless of BMI (Fig 2). For white participants at normal body weight (BMI < 26 kg/m²), the percentage of participants with CKD at each decile of systolic blood pressure was greater with greater blood pressure (20% at < 130 mm Hg, 28.5% at 130 to 139 mm Hg, 33.2% at 140 to 149 mm Hg, $P < 0.001$; and 41% at > 150 mm Hg, $P < 0.001$). The same relationship was observed for African American participants; although significant, the percentages of participants at given blood pressure deciles were lower compared with white participants (14.6%, 19.6%, 27.6%, and 34.7%, respectively; $P < 0.001$). Trends were similar for participants with BMI of 26 to 30 kg/m² and obesity (BMI > 30 kg/m²; Fig 1).

In the subgroup of participants with hypertension and CKD stages 2 to 4 (Table 2), the

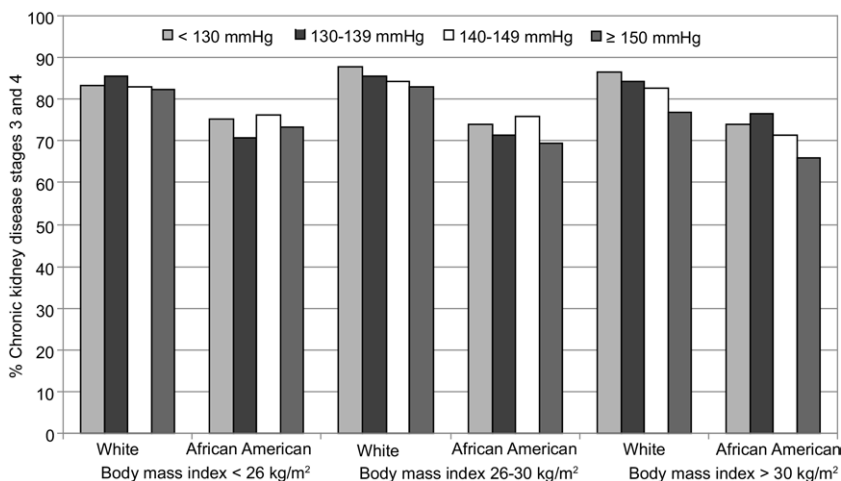


Figure 2. In KEEP participants with CKD, percentage with CKD stages 3 to 4, stratified by African American or white race, systolic blood pressure, and body mass index.

Table 2. Prevalence of Chronic Kidney Disease Stage by Systolic Blood Pressure and Characteristics

	Systolic Blood Pressure (mm Hg)										P†
	Hypertension Only*		<130		130-139		140-149		≥150		
	Stage 2	Stages 3-4	Stage 2	Stages 3-4	Stage 2	Stages 3-4	Stage 2	Stages 3-4	Stage 2	Stages 3-4	
KEEP (No.)	3,296	12,508	1,117	4,831	680	2,894	666	2,495	1,259	3,649	
Overall	20.9	79.1	18.8	81.2	19.0	81.0	21.1	78.9	25.6	74.4	<0.001
Age (y)											
18-30	52.7	47.3	54.0	46.0	61.5	38.5	41.7	58.3	60.0	40.0	
31-45	42.8	57.2	36.1	63.9	45.1	54.9	38.7	61.3	50.8	49.3	
46-60	26.4	73.6	20.3	79.7	22.5	77.5	28.8	71.2	35.9	64.1	
61-75	17.4	82.6	12.0	88.0	15.5	84.5	17.1	82.9	23.5	76.5	
>75	13.0	87	9.7	90.3	9.4	90.6	14.5	85.5	16.6	83.4	
Sex											
Men	24.1	75.9	18.3	81.7	23.0	77.0	24.7	75.3	30.1	69.9	
Women	19.4	80.6	19.0	81.0	17.1	82.9	19.4	80.6	23.6	76.4	
Race											
White	16.2	83.8	14.3	85.7	15.2	84.8	16.9	83.1	20.0	80.0	
African American	27.6	72.4	25.6	74.4	25.7	74.3	26.6	73.4	32.0	68.0	<0.001
Other	27.4	72.6	25.9	74.1	24.0	76.0	27.0	73.0	35.4	64.6	
Hispanic											
Yes	26.9	73.1	26.7	73.3	25.9	74.1	25.2	74.8	33.5	66.5	
No	20.4	79.6	18.0	82.0	18.5	81.5	20.8	79.2	25	75.0	
Education											
<High school	20.9	79.1	18.4	81.6	16.9	83.1	20.2	79.8	26	74.0	<0.001
≥High school	20.7	79.3	18.7	81.3	19.5	80.5	21.2	78.8	25.4	74.6	<0.001
Current smoker	30.9	69.1	26.5	73.5	30.9	69.1	28.8	71.2	39.6	60.4	0.002‡
Body mass index ≥ 30 kg/m ²	22.6	77.4	18.4	81.6	19.7	80.3	22.4	77.6	28.8	71.2	<0.001
Diabetes§	23.0	77.0	18.5	81.5	19.9	80.1	23.8	76.2	29.0	71.0	<0.001
Cardiovascular disease§	18.7	81.3	14.5	85.5	18.2	81.8	20.7	79.3	23.4	76.6	0.2‡
High cholesterol§	19.8	80.2	16.1	83.9	19.5	80.5	19.6	80.4	27	73.0	<0.001
NHANES (No.)	684	1,530	298	630	133	323	97	225	296	544	
Overall	30.7	69.3	35.8	64.2	28.5	71.5	27.4	72.6	35.6	64.4	<0.001
Age (y)											
18-30	78.5	—	87.5	—	98.0	—	100	0	—	—	
31-45	67.6	32.4	72.7	27.3	52.4	47.6	75.2	—	83.7	—	
46-60	40.3	59.7	30.9	69.1	37.7	62.3	47.1	52.9	59.5	40.5	
61-75	27.1	72.9	24.6	75.4	23.9	76.1	20.2	79.8	38.4	61.6	
>75	18.8	81.2	14.5	85.5	16.0	84	12.2	87.8	24.4	75.6	

(Continued)

Table 2 (Cont'd). Prevalence of Chronic Kidney Disease Stage by Systolic Blood Pressure and Characteristics

	Systolic Blood Pressure (mm Hg)										P†
	Hypertension Only*										
	Stage 2	Stages 3-4	<130		130-139		140-149		≥150		
	Stage 2	Stages 3-4	Stage 2	Stages 3-4	Stage 2	Stages 3-4	Stage 2	Stages 3-4	Stage 2	Stages 3-4	
Sex											
Men	36.8	63.2	38.9	61.1	36.3	63.7	33.9	66.1	44.0	56.0	
Women	26.4	73.6	33.3	66.7	22.5	77.5	22.6	77.4	31.3	68.7	
Race											
White	27.1	72.9	33.2	66.8	24.2	75.8	22.5	77.5	32.9	67.1	
African American	42.6	57.4	40.1	59.9	42.2	57.8	55.3	44.7	42.5	57.5	<0.001
Other	48.5	51.5	54.7	45.3	49.0	51	49.1	50.9	47.4	52.6	
Hispanic											
Yes	49.2	50.8	50.1	49.9	49.1	50.9	45.6	54.4	52.4	47.6	
No	29.4	70.6	34.7	65.3	26.8	73.2	26.2	73.8	34.4	65.6	
Education											
<High school	30.8	69.2	35.3	64.7	26.9	73.1	26.0	74.0	38.5	61.5	<0.001
≥High school	30.7	69.3	35.9	64.1	29.1	70.9	27.9	72.1	34.3	65.7	<0.001
Current smoker	44.4	55.6	52.0	48.0	38.8	61.2	38.6	61.4	62.2	37.8	0.002‡
Body mass index ≥											
30 kg/m ²	36.9	63.1	41.8	58.2	35.6	64.4	35.2	64.8	41.5	58.5	<0.001
Diabetes§	34.8	65.2	38.6	61.4	42.0	58	29.3	70.7	36.7	63.3	<0.001
Cardiovascular											
disease§	22.3	77.7	20.1	79.9	18.7	81.3	15.5	84.5	28.3	71.7	0.2‡
High cholesterol§	28.1	71.9	29.5	70.5	27.2	72.8	25.7	74.3	30.8	69.2	<0.01

Note: Stage 2 is defined as eGFR of 60 to 89 mL/min/1.73 m² and albumin-creatinine ratio of 30 mg/g or greater; stages 3 to 4, eGFR of 15 to 59 mL/min/1.73 m². Presence of dash in cell indicates missing value because of unreliable estimates. Conversion factor for eGFR in mL/s/1.73 m², ×0.01667.

Abbreviations: eGFR, estimated glomerular filtration rate; KEEP, Kidney Early Evaluation Program; NHANES, National Health and Nutrition Examination Survey.

*KEEP and NHANES, defined as self-reported hypertension or increased blood pressure (Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure).

†Comparing NHANES versus KEEP for hypertensive patients with chronic kidney disease stages 2 to 4.

‡Estimate is not reliable because (SE/percentage difference) is greater than 0.30.

§Self reported.

||All analysis related to smoking status, self-reported cardiovascular disease, and self-reported high cholesterol level using NHANES data are limited to participants 20 years or older. Race in NHANES: non-Hispanic white, non-Hispanic black, and other.

databases differed significantly in the proportions with CKD stages 3 and 4 (79.1% in KEEP versus 69.3% in NHANES; $P < 0.01$). The databases also differed in proportions of African Americans (72.4%, KEEP; 57.4%, NHANES; $P < 0.01$), current smokers (69.1%, 55.6%; $P < 0.01$), obesity (77.4%, 63.1%; $P < 0.01$), self-reported diabetes (77%, 65.2%; $P < 0.01$), and hypercholesterolemia (80.2%, 71.9%; $P < 0.01$). Distributions of these variables were similar between databases for any given systolic pressure decile. More KEEP participants than NHANES participants with CKD stages 3 and 4 had hypertension, and the prevalence of CKD stages 3 and 4 increased with age in KEEP and NHANES.

In the KEEP database, the probability of not reporting hypertension when present was greater in participants older than 60 years, African Americans, and participants with self-reported diabetes, family history of hypertension, obesity, and CKD (Table 3). The probability of having a target blood pressure was greatest for participants younger than 46 years and least for those

Table 3. Odds Ratios of Measured Hypertension in KEEP Participants Who Self-Reported No Hypertension

	Odds Ratio (95% confidence interval)	<i>P</i>
Age (y)		
18-30	0.40 (0.36-0.44)	<0.001
31-45	0.62 (0.58-0.66)	<0.001
46-60 (reference)	1.00	
61-75	1.56 (1.44-1.68)	<0.001
>75	1.88 (1.64-2.16)	<0.001
Sex		
Men (reference)	1.00	
Women	0.57 (0.54-0.61)	<0.001
Race		
White	1.00	
African American	1.14 (1.07-1.22)	<0.001
Other	0.85 (0.79-0.91)	<0.001
Current smoker	0.95 (0.88-1.03)	0.2
Self-reported diabetes	3.34 (3.12-3.57)	<0.001
Family history of diabetes	1.03 (0.98-1.09)	0.3
Family history of hypertension	1.26 (1.17-1.35)	<0.001
Body mass index ≥ 30 kg/m ²	2.27 (2.14-2.40)	<0.001
Chronic kidney disease	3.45 (3.21-3.70)	<0.001

Note: Hypertension was defined by the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure.

Abbreviation: KEEP, Kidney Early Evaluation Program.

Table 4. Odds Ratios of Meeting Target Blood Pressure in KEEP Participants Who Self-Reported Hypertension

	Odds Ratio (95% confidence interval)	<i>P</i>
Age (y)		
18-30	1.85 (1.61-2.13)	<0.001
31-45	1.28 (1.19-1.38)	<0.001
46-60 (reference)	1.00	
61-75	0.89 (0.84-0.94)	<0.001
>75	0.77 (0.71-0.84)	<0.001
Sex		
Men (reference)	1.00	
Women	1.22 (1.16-1.28)	<0.001
Race		
White	1.00	
African American	0.77 (0.73-0.81)	<0.001
Other	1.05 (0.99-1.13)	0.1
Current smoker	1.06 (0.98-1.14)	0.2
Self-reported diabetes	0.49 (0.47-0.52)	<0.001
Family history of diabetes	1.03 (0.98-1.08)	0.3
Family history of hypertension	0.94 (0.89-1.00)	0.04
Body mass index ≥ 30 kg/m ²	0.71 (0.68-0.74)	<0.001
Chronic kidney disease	0.42 (0.40-0.44)	<0.001

Abbreviation: KEEP, Kidney Early Evaluation Program.

older than 60 years, African Americans, and those with self-reported diabetes, obesity, or CKD (Table 4).

The probability of not reporting kidney impairment when present was significantly greater for participants older than 60 years (odds ratio [OR], 1.75; 95% confidence interval [CI], 1.64 to 1.87; $P < 0.001$), with pulse pressure greater than 60 mm Hg (OR, 1.35; 95% CI, 1.20 to 1.51; $P < 0.001$), or who were obese (OR, 1.10, 95% CI, 1.03 to 1.17; $P < 0.001$) or had diabetes (OR, 1.08; 95% CI, 1.02 to 1.14; $P < 0.001$) or microalbuminuria (OR, 2.14; 95% CI, 1.99 to 2.29; $P < 0.001$). KEEP participants with systolic blood pressure greater than 160 mm Hg had the greatest probability of reporting kidney impairment when present (OR, 0.61; 95% CI, 0.55 to 0.67; $P < 0.001$).

DISCUSSION

We examined the relationship between CKD stage and systolic blood pressure in the KEEP and NHANES 1999 to 2006 databases. Our data confirm previous reports that at greater systolic blood pressures, the probability of kidney impair-

ment is also greater, a relationship that held regardless of race or sex. Because of the recruitment of participants with CKD risk factors and self-concern for CKD, KEEP was enriched with relatively more participants with early kidney disease than NHANES at all systolic blood pressure deciles greater than 130 mm Hg. The KEEP database also had greater representation of African Americans with hypertension and greater percentages of participants with obesity and diabetes than NHANES.

Both databases showed baseline systolic blood pressure to be independently associated with the presence of early kidney disease, and CKD stages 3 and 4 were more common than stage 2 at all systolic blood pressure deciles greater than 130 mm Hg. Systolic blood pressure level is a clinically useful predictor of CKD in persons with diabetes¹⁷ and an independent cardiovascular risk factor for those older than 50 years.¹⁶ Our results confirm these relationships.

Microalbuminuria was more prevalent in the KEEP than NHANES database. Recent data show that microalbuminuria is a biomarker strongly associated with risk of essential hypertension development,²³ and it determines the need for additional blood pressure medication to achieve blood pressure goals.²⁴ Clearly, early aggressive reduction of systolic blood pressure with appropriate agents increases kidney protection, slows the progression of kidney damage,²⁵ and reduces cardiovascular risk.²⁶ In KEEP, the probability of not reporting kidney impairment when present was significantly greater for participants with microalbuminuria, providing an additional reason to assess microalbuminuria in hypertensive patients, given this lack of awareness.

Interestingly, a greater prevalence of CKD was noted in white than African American participants in these databases. However, in KEEP, numbers of both white and African American participants with CKD were greater at any given systolic blood pressure level, a trend unrelated to BMI. Our data are not in accordance with studies showing that African Americans and members of other minority groups are more likely than whites to develop CKD.²⁷ One possible explanation for this observation is that more African Americans die at earlier CKD stages, before reaching stages 3 and 4. Evidence is strong that African Americans with CKD have more poorly con-

trolled hypertension than white counterparts, particularly in early disease stages,²⁸ and hypertension onset tends to be earlier and more severe in African Americans, leading to more end-organ damage and premature cardiovascular death than in white populations.¹⁹

Hypertension with CKD is much more common in the KEEP than in the NHANES database, and the KEEP database shows greater rates of CKD stages 3 and 4 than the NHANES database in African Americans. Our analysis does not answer the question of whether increases in blood pressure lead to more advanced kidney disease or vice versa. Lack of awareness of CKD presence may lead to less vigilant blood pressure control. CKD can be undetected until advanced stages; KEEP, as a targeted community-based health screening program with a larger CKD sample size than NHANES, may allow improved exploration of these health associations.

In the KEEP database, we found that African Americans not reporting hypertension on history had a 14% rate of having increased measured blood pressure, and African Americans with known hypertension had a 33% greater rate of not meeting blood pressure control guidelines. This analysis provides compelling evidence that the problem of hypertension and kidney impairment may be much greater than estimated rates and delineates the need for strategies to identify and treat people at risk in the community, given the profound heterogeneity among racial groups. KEEP participants receive laboratory results and educational materials about kidney disease risks and treatment opinions, and their physicians receive laboratory results and clinical practice guidelines for CKD care.²⁹ This is an effort to improve knowledge and awareness, leading to improved blood pressure levels and CKD results.

Overweight prevalence in the United States is approximately 66%.³⁰ Obesity was more prevalent in KEEP than NHANES. We noted a consistently greater CKD prevalence with greater weight regardless of race and sex in both KEEP and NHANES. This is consistent with previous studies that evaluated other databases.³¹ Our data also support evidence from long-term observational studies that show a correlation between BMI and CKD progression.^{32,33} Not surprisingly, greater weight was also associated with greater blood pressure deciles. This consistent

relationship is important because obesity increases not only cardiovascular risk, but also the probability of developing CKD.

More KEEP than NHANES participants self-reported diabetes; in both databases, hypertension prevalence was more than 85% in participants who self-reported diabetes. These results are in accordance with earlier results showing that hypertension is a common problem in patients with diabetes.³⁴

Our study is limited by the cross-sectional nature of both databases. These databases rely on voluntary physical examinations and screening histories, including self-reports of such diseases as hypertension, diabetes, and CKD. Another study limitation is the low percentage of NHANES participants with eGFR less than 30 mL/min/1.73 m² to compare with the more robust KEEP data. In addition, KEEP participants may have better hypertension awareness than NHANES participants because the presence of hypertension is a KEEP eligibility criterion.

In conclusion, this analysis shows the magnitude and complexity of systolic hypertension in different groups in the United States. Systolic blood pressure as a component of hypertension was associated with lower eGFR in both people at risk of CKD (KEEP) and the general population (NHANES). White participants had more CKD than African American participants. Obese and diabetic participants had greater rates of early kidney disease at greater systolic blood pressure deciles. Screening programs improve public health, improve knowledge and communication, enhance adherence to recommended therapies, and improve clinical outcomes. The targeted nature of the KEEP screening program and the large number of participants contrast with NHANES and highlight the value of blood pressure assessments in both populations.

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