ORIGINAL ARTICLE

Prevalence, Determinants, and Clinical Significance of Masked Hypertension in a Population-Based Sample of African Americans: The Jackson Heart Study

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BACKGROUND
The disproportionate rates of cardiovascular disease in African Americans may, in part, be due to suboptimal assessment of blood pressure (BP) with clinic BP measurements alone. To date, however, the prevalence of masked hypertension in African Americans has not been fully delineated. The purpose of this study was to evaluate masked hypertension prevalence in a large population-based sample of African Americans and examine its determinants and association with indices of target organ damage (TOD).

METHODS
Clinic and 24-hour ambulatory BP monitoring were conducted in 972 African Americans enrolled in the Jackson Heart Study. Common carotid artery intima-media thickness, left ventricular mass index, and the urinary albumin:creatinine excretion ratio were evaluated as indices of TOD.

RESULTS
Masked hypertension prevalence was 25.9% in the overall sample and 34.4% in participants with normal clinic BP. All indices of TOD were significantly higher in masked hypertensives compared to sustained normotensives and were similar between masked hypertensives and sustained hypertensives. Male gender, smoking, diabetes, and antihypertensive medication use were independent determinants of masked hypertension in multivariate analyses.

CONCLUSIONS
In this population-based cohort of African Americans, approximately one-third of participants with presumably normal clinic BP had masked hypertension when BP was assessed in their daily environment. Masked hypertension was accompanied by a greater degree of TOD in this cohort.

Keywords: African Americans; ambulatory blood pressure monitoring; blood pressure; hypertension; masked hypertension; target organ damage.

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Hypertension is more prevalent, more severe, and causes a disproportionate number of premature disabilities and deaths from myocardial infarction, stroke, and end-stage renal disease in African Americans than in any other racial/ethnic group in the United States.[1–3] Evidence further shows that hypertension explains most of the racial disparity in mortality rates.[4] Accordingly, in order to close the health disparity gap, the careful measurement and evaluation of blood pressure (BP) levels among African Americans is critical to (i) screen for hypertension and (ii) evaluate BP control among individuals treated for hypertension.

Clinic-based BP measurements may incorrectly diagnose a subset of individuals who present as having nonelevated BP in the clinic, but have elevated BP when measured within the context of their daily environment.[5] Evidence suggests this phenomenon, referred to as masked hypertension, has important prognostic implications for a variety of health outcomes.[6] Masked hypertensives are at a greater risk of target organ damage (TOD), cardiac dysfunction, and mortality compared to individuals with normotensive clinic and 24-hour BP (i.e., sustained normotension), and have TOD and mortality rates comparable to individuals who present

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as hypertensive both in the clinic and during 24-hour BP monitoring (i.e., sustained hypertension).[6–10] Despite recognition of masked hypertension as a clinically important phenomenon, few studies have quantified the prevalence of masked hypertension in African Americans. If prevalence rates among African American populations are high, it could have tremendous implications for clinical practice, as it would suggest a large proportion of African Americans have undiagnosed or poorly controlled hypertension.

The purpose of this study was to evaluate the prevalence of masked hypertension in a population-based sample of African Americans who were enrolled in the Jackson Heart Study (JHS), the largest epidemiologic investigation of cardiovascular disease (CVD) among African Americans to date. As secondary objectives, we examined the determinants of masked hypertension and evaluated its association with indices of TOD in this sample.

METHODS

Study population

The JHS is a large, single-site, population-based study of CVD among African Americans. Details of study design, recruitment, and data collection have been previously described.[11–14] Briefly, 5,301 African American adults were recruited from the Jackson, Mississippi metropolitan area and underwent a baseline examination that consisted of interviewer and self-administered questionnaires and clinical examinations that included BP measurements, urine and blood sampling, echocardiography, and carotid ultrasonography all collected using standardized protocols. All participants were invited to participate in a 24-hour ambulatory BP monitoring (ABPM) session. In total, 1,144 (21.6%) participants voluntarily underwent ABPM and were included in the present analyses. The JHS adhered to the guidelines set forth by the Declaration of Helsinki and was approved by institutional review boards of participating institutions. All participants provided informed consent.

Clinic BP

Clinic BP was measured using a Hawksley random-zero sphygmomanometer (Hawksley and Sons Ltd.). Measurements were taken after a 5-minute silent rest in the right arm of seated participants whose back and arm were supported.[15] Cuff size was determined by upper-arm circumference. The average of 2 measures taken 1-minute apart was used as the representative clinic BP.

Ambulatory BP monitoring

Participants underwent 24-hour ABPM using a noninvasive, portable BP monitor (Model 90207; SpaceLabs Medical, Rockville, MD) as previously described.[11,16] A BP cuff was fitted to the participant's nondominant arm with cuff size determined by upper-arm circumference. The device was programmed to obtain measurements at 20-minute intervals throughout the 24-hour period. Prior to each session, the monitor was calibrated against a Baum mercury sphygmomanometer (WA Baum, Copiaque, NY) using 3–5 simultaneous ABPM and clinic BP readings.

Hypertension classifications

Clinic hypertension was defined as mean clinic BP ≥140/90 mm Hg. Ambulatory hypertension was based on awake ABP and defined as mean BP ≥135/85 mm Hg in accordance with international guidelines.[17,18] Hypertension subgroups were defined as follows: sustained normotension was defined as having both normal clinic BP (<140/90 mm Hg) and awake ABP (<135/85 mm Hg); sustained hypertension was defined as having both clinic hypertension and ambulatory hypertension; masked hypertension was defined as having normal clinic BP and ambulatory hypertension; and white coat hypertension was defined as having clinic hypertension and normal awake ABP.

Echocardiography

Two-dimensional echocardiography was performed using the Sonos-4500 (Philips Medical Systems) ultrasound machine as previously described.[11] Briefly, the imaging protocol consisted of a 30-minute examination from parasternal, apical, and subcostal windows. All 4 chambers were imaged for assessment of left ventricular (LV) dimensions and systolic function to allow for calculation of LV mass. LV mass was calculated according to Devereux's formula.[19] LV mass index was calculated by dividing LV mass by estimated body surface area.

Carotid ultrasonography

Electrocardiography-gated, B-mode, and spectral steered Doppler with an integrated ultrasound machine was used to obtain carotid artery images.[11] A detailed summary of ultrasonography methodology can be found in Supplementary Methods online. Briefly, mean and maximum values were obtained for each carotid artery segment, side, and wall. Recordings during maximum diastole (R wave) were used for analysis. Maximum likelihood estimates were calculated by adjusting for missing data in the collecting, processing, and reading of images. Common carotid artery intima-media thickness represented a maximum likelihood estimate of mean far-wall of average values across the right and left side of the common carotid artery.

24-Hour urine collection

All participants were invited to contribute a 24-hour urine sample during the baseline examination. Consenting participants (n = 740) were given a 3-l jug and were instructed to collect a 24-hour urine sample by discarding the last voided urine before going to sleep and then collecting all voided urine up to and including the last void the following evening. Upon completion, urine samples were aliquoted and sent for analysis of albumin, creatinine, sodium, and potassium excretion.[11] The urinary albumin:creatinine excretion ratio was quantified. Further details on 24-hour urine collection are provided in Supplementary Methods online.

Covariates and additional variables

Age, gender, lifestyle behaviors (cigarette smoking, alcohol drinking, physical activity), and selected CVD risk factors (body mass index (BMI), diabetes, hypercholesterolemia, and high-sensitivity C-reactive protein) were included as standard covariates. Marital status, socioeconomic status (education, income), and lipids (total cholesterol, high- and low-density lipoproteins, triglycerides) were included to examine their relationship with masked hypertension. A detailed summary of methodology for these variables are reported in Supplementary Methods online.

Statistical analyses

Among the 1,144 participants who underwent 24-hour ABPM, analyses were restricted to participants with successful ABPM (>75% of valid readings) and complete diary information. Supplementary Table 1 online shows the characteristics of JHS participants included (n = 972) and excluded (n = 4,329) from current analyses.

The prevalence of masked hypertension was defined in 2 ways: (i) prevalence among the overall sample; and (ii) prevalence among those with normal clinic BP (<140/90 mm Hg; n = 733). To examine the prevalence of masked hypertension with increasing clinic BP, participants were stratified into 5 categories according to their clinic BP: (i) <100/70 mm Hg, (ii) 100–109/70–74 mm Hg, (iii) 110–119/75–79 mm Hg, (iv) 120–129/80–84 mm Hg; and (v) 130–139/85–89 mm Hg. As some have contended that both awake and sleep BP be used to define masked hypertension,[20] prevalence data were secondarily quantified defining masked hypertension as either elevated awake (≥135/85 mm Hg) or sleep (≥120/70 mm Hg) ABP.

Participant characteristics were calculated by hypertension subgroup. Analysis of covariance was then used to evaluate differences in measures of TOD among hypertension subgroups after adjusting for age, gender, and BMI (model 1). Subsequent progressive models additionally controlled for: current smoking, physical activity, and heavy alcohol drinking (model 2); and diabetes, hypercholesterolemia, and high-sensitivity C-reactive protein (model 3). Urinary albumin:creatinine excretion ratio values were left skewed and transformed using a natural logarithm to normalize the skewed distribution.

Logistic regression was used to identify factors that were associated with masked hypertension. For these analyses, the sample was restricted to individuals with normal clinic BP. Crude odds ratios were initially calculated. Subsequently, odds ratios were calculated with partial adjustment for age, gender, and BMI (model 1) and further adjustment for all variables significantly associated with masked hypertension in univariate analyses (model 2). Analyses were then repeated testing the following interactions: gender × BMI, gender × age, age × BMI, smoking × BMI, and age × antihypertensive medication treatment. The fit of the regression models were assessed by the Hosmer–Lemeshow goodness-of-fit test.

In order to compare with other population-based studies,[21–23] primary analyses included participants both on and not on antihypertensive medication (e.g., treated and untreated). However, because masked hypertension among treated and untreated individuals underscores 2 separate issues (uncontrolled hypertension vs. undiagnosed hypertension), as a sensitivity analysis, the above analyses were repeated separately for treated (n = 565) and untreated (n = 407) participants. Statistical analyses were performed using SPSS version 18.0 (SPSS, Chicago, IL).

RESULTS

Masked hypertension prevalence

The prevalence of masked hypertension was 25.9% in the overall sample and 34.4% among the 733 participants with normal clinic BP. When stratified by antihypertensive medication usage, masked hypertension prevalence among treated participants was 28.1% and 39.1% in the overall sample and in participants with normal clinic BP, respectively. Among untreated participants, masked hypertension prevalence was 20.6% in the overall sample and 25.4% in participants with normal clinic BP.

Figure 1 shows the prevalence of masked hypertension across clinic BP categories. Masked hypertension prevalence increased with clinic BP levels, with individuals in the stage 2 prehypertension range (130/85–139/89 mm Hg) having a prevalence of 51.4%. Similar trends were observed when

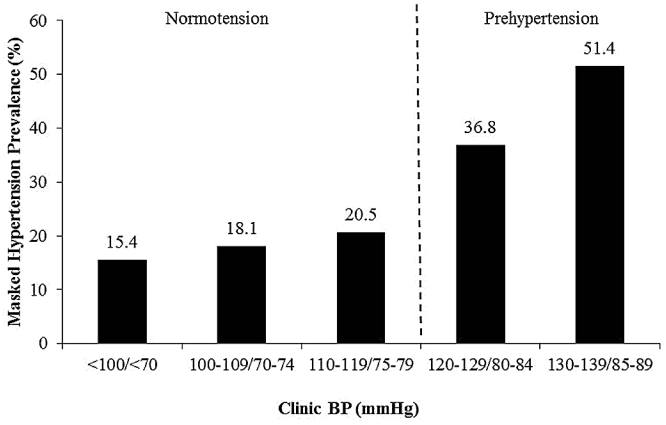

Figure 1. Prevalence of masked hypertension by clinic blood pressure category in the Jackson Heart Study.

Table 1. Demographics and clinical characteristics by hypertension classification in the entire study population

Variable	Sustained normotension (n = 481)	White coat hypertension (n = 73)	Masked hypertension (n = 252)	Sustained hypertension (n = 166)	P value ANOVA
Age (years)	57.2 ± 11.4	60.9 ± 9.8*	60.4 ± 10.3**	60.9 ± 11.0**	<0.001
Male (%)	26.4	26.0	34.5*	39.8**,†	<0.01
Current smoker (%)	7.7	4.1	14.7**,†	13.9*,†	<0.01
Heavy drinker (%)	24.2	18.1	29.2	23.9	0.22
Married (%)	52.3	54.8	54.8	55.4	0.87
Education (% ≤ HS)	37.0	30.1	35.3	39.2	0.58
Employment (% full-time)	40.3	35.6	36.9	36.1	0.66
Income level (% ≥ $50,000)	29.1	26.0	31.3	22.9	0.28
Postmenopausal (%)	88.2	91.8	88.2	93.4	0.47
Diabetes (%)	17.3	12.9	29.6***,††	24.1	<0.001
Hypercholesterolemia (%)	32.0	33.3	36.5	30.5	0.59
Antihypertensive medication (%)	54.4	73.5**	69.1***	69.7***	<0.001
Physical activity score	8.4 ± 2.6	8.1 ± 2.6	8.3 ± 2.6	8.1 ± 2.5	0.79
BMI (kg/m^2)	31.5 ± 6.8	31.5 ± 7	30.6 ± 5.7	31.0 ± 6.3	0.44
Total cholesterol (mg/dl)	200.0 ± 39.4	209.2 ± 43.8	202.9 ± 40.5	201.8 ± 36.6	0.29
HDL cholesterol (mg/dl)	54.0 ± 14.7	54.8 ± 16.2	54.5 ± 14.8	54.1 ± 16.1	0.92
LDL cholestesrol (mg/dl)	124.9 ± 35.3	131.2 ± 38.1	127.4 ± 38.2	124.9 ± 33.4	0.51
Triglycerides (mg/dl)	106.3 ± 91.1	124.9 ± 81.4	104.8 ± 62.2	115.1 ± 74.6	0.08
hsCRP (mg/dl)	0.50 ± 0.72	0.51 ± 0.86	0.53 ± 0.87	0.48 ± 0.67	0.80
Sodium excretion (mEq/24 h)	157.1 ± 68.4	154.5 ± 72.8	163.7 ± 72.8	158.0 ± 69.4	0.82
Potassium excretion (mEq/24 h)	49.3 ± 33.8	47.6 ± 19.5	49.5 ± 23.0	51.1 ± 29.0	0.92
Clinic SBP (mm Hg)	117.8 ± 11.2	145.7 ± 16.7***	124.5 ± 9.9***,†††	150.2 ± 14.6***,††,‡‡‡	<0.001
Clinic DBP (mm Hg)	73.7 ± 8.0	85.4 ± 10.2***	75.1 ± 8.9†††	85.8 ± 11.1***,‡‡‡	<0.001
Clinic PP (mm Hg)	44.1 ± 10.4	60.4 ± 20.0***	49.5 ± 10.6***,†††	64.4 ± 18.2***,†,‡‡‡	<0.001
Awake SBP (mm Hg)	121.5 ± 7.8	124.9 ± 6.4**	140.2 ± 9.4***,†††	146.2 ± 11.9***,†††,‡‡‡	<0.001
Awake DBP (mm Hg)	74.3 ± 6.2	74.2 ± 6.5	85.3 ± 8.0***,†††	87.6 ± 8.9***,†††,‡‡	<0.001
Sleep SBP (mm Hg)	113.3 ± 11	119.3 ± 11.7***	130.7 ± 14.3***,†††	137.2 ± 15.7***,†††,‡‡‡	<0.001
Sleep DBP (mm Hg)	64.7 ± 8.0	66.2 ± 9.5	74.4 ± 11.1***,†††	76.6 ± 9.4***,†††,‡	<0.001

Data are presented as mean ± SD or percentage.

Abbreviations: ANOVA, analysis of variance; BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HS, high school; hsCRP, high-sensitivity C-reactive protein; LDL, low-density lipoprotein; PP, pulse pressure; SBP, systolic blood pressure.

*P < 0.05, **P < 0.01, ***P < 0.001 vs. sustained normotension; †P < 0.05, ††P < 0.01, †††P < 0.001 vs. white coat hypertension; ‡P < 0.05, ‡‡P < 0.01, ‡‡‡P < 0.001 vs. masked hypertension.

participants were stratified by antihypertensive medication use (Supplementary Figure 1 online).

The prevalence of masked hypertension when defined as either elevated awake or sleep ABP is presented in Supplementary Table 2 online.

Demographics and clinical characteristics by hypertension subgroup

Masked hypertensives were older, more likely to be male, more often current smokers, more likely to have diabetes, more often taking antihypertensive medications, had higher clinic systolic BP, and had higher ABP compared to sustained normotensives (Table 1). There were no differences between masked hypertensives and sustained hypertensives with the exception of clinic and ambulatory BPs, which were lower in masked hypertensives. Similar trends were observed for participants on or not on antihypertensive medication (data not shown).

TOD by hypertension subgroup

Masked hypertensives had significantly greater common carotid artery intima-media thickness, LV mass index, and

Table 2. Indices of target organ damage by hypertension classification in the entire study population

Variable	Sustained normotension (n = 481)	White coat hypertension (n = 73)	Masked hypertension (n = 252)	Sustained hypertension (n = 166)	P value AN(C)OVA
CCIMT (mm)					
Unadjusted	0.70 ± 0.17	0.73 ± 0.18	0.78 ± 0.18***,†	0.81 ± 0.27***,††	<0.001
Model 1	0.71 ± 0.01	0.71 ± 0.02	0.76 ± 0.01***,†	0.79 ± 0.01***,††	<0.001
Model 2	0.71 ± 0.01	0.72 ± 0.02	0.76 ± 0.01**	0.78 ± 0.01***,††	<0.001
Model 3	0.72 ± 0.01	0.72 ± 0.02	0.75 ± 0.01*	0.78 ± 0.02***,†	<0.01
LVMI (g/m^2)					
Unadjusted	74.3 ± 20.2	75.0 ± 20.9	85.6 ± 25.2***,†††	83.9 ± 25.2***,††	<0.001
Model 1	75.3 ± 1.0	74.5 ± 2.6	84.8 ± 1.4***,††	82.6 ± 1.7***,†	<0.001
Model 2	74.9 ± 1.0	74.3 ± 2.6	83.1 ± 1.5***,††	81.2 ± 1.8**,†	<0.001
Model 3	75.4 ± 1.1	74.1 ± 2.7	82.1 ± 1.5***,††	80.5 ± 1.8*,†	<0.001
UACR (Log)					
Unadjusted	1.86 ± 0.92	2.07 ± 1.37	2.25 ± 1.32***	2.48 ± 1.40***,†	<0.001
Model 1	1.86 ± 0.06	2.03 ± 0.15	2.27 ± 0.09***	2.47 ± 0.10***,†	<0.001
Model 2	1.86 ± 0.06	1.97 ± 0.15	2.28 ± 0.09***	2.45 ± 0.10***,††	<0.001
Model 3	1.89 ± 0.06	2.03 ± 0.15	2.17 ± 0.09**	2.35 ± 0.10***	<0.001

Data are presented as mean ± SD (unadjusted analyses) or estimated marginal mean ± SE (adjusted analyses). Model 1 adjusts for age, gender, BMI. Model 2 adjusts for covariates in model 1 + current smoking status, physical activity score, and heavy alcohol drinking. Model 3 adjusts for covariates in model 2 + diabetes status, hypercholesterolemia, and hsCRP.

Abbreviations: ANCOVA, analysis of covariance; BMI, body mass index; CCIMT, common carotid artery intima-media thickness; hsCRP, high-sensitivity C-reactive protein; LVMI, left ventricular mass index; UACR, urinary albumin creatinine ratio.

*P < 0.05, **P < 0.01, ***P < 0.001 vs. sustained normotension; †P < 0.05, ††P < 0.01, †††P < 0.001 vs. white coat hypertension.

urinary albumin:creatinine excretion ratio compared to sustained normotensives in unadjusted and adjusted models (Table 2). Common carotid artery intima media thickness, LV mass index, and urinary albumin:creatinine excretion ratio were all similar between masked hypertensives and sustained hypertensives in unadjusted and adjusted models. The pattern of results were similar when subgroups were analyzed among participants on or not on antihypertensive medication (Supplementary Table 3 online).

Determinants of masked hypertension

In unadjusted models, age, gender, heavy drinking, smoking, diabetes, antihypertensive medication, and clinic BP category were associated with masked hypertension (Table 3). In multivariate-adjusted models, gender, smoking, diabetes, antihypertensive medication, and clinic BP category remained significantly associated with masked hypertension. All interactions terms tested were not significant (P > 0.05). Determinants of masked hypertension for treated and untreated participants are shown in Supplementary Tables 4 and 5 online.

DISCUSSION

Despite the well-known racial disparities in CVD, few studies have quantified masked hypertension in all-African American populations and none have done so among African Americans in the general population. In this community-based sample of African Americans there were several important findings. First, we found that approximately one-third of JHS participants with seemingly normal clinic BP had masked hypertension. Second, a large proportion of masked hypertensives had stage 2 prehypertension. Third, male gender, smoking, diabetes antihypertensive medication use, and clinic BP were independent determinants of masked hypertension. Finally, the extent of TOD among masked hypertensives was higher than sustained normotensives and resembled that of sustained hypertensives.

Heterogeneity among existing population-based studies makes it difficult to determine whether the prevalence observed in the JHS cohort might indicate that African Americans have a greater prevalence of masked hypertension compared to other race/ethnicities. Prevalence rates in other population-based studies were lower in comparison to the JHS cohort, ranging from 8% to 17% in the overall sample (vs. 26% in JHS) and 11%–23% among individuals with normal clinic BP (vs. 34% in JHS).[21–24] In population-based studies in Japan[21] and Denmark,[22] prevalence rates of masked hypertension (overall sample, treated, and untreated: 17%, 19%, and 16% in Japan; 12%, 10%, and 13% in Denmark) were lower in comparison to the JHS cohort when masked hypertension was defined using the same definition employed in the present study. Using this same definition, masked hypertension prevalence was also lower in the EPOGH project (12%),[23] a population-based study of

Table 3. Factors associated with masked hypertension in multivariate analysis

	Unadjusted		Model 1		Model 2	
Variable	**Odds ratio (95% CI)**	***P***	**Odds ratio (95% CI)**	***P***	**Odds ratio (95% CI)**	***P***
Age (years)	1.03 (1.01–1.04)	<0.001	1.03 (1.01–1.04)	<0.001	1.01 (0.99–1.03)	0.13
Male gender	1.47 (1.06–2.04)	0.02	1.43 (1.02–2.00)	0.04	1.74 (1.18–2.56)	<0.01
BMI (kg/m^2)	0.98 (0.95–1.00)	0.08	0.98 (0.96–1.01)	0.23	-	-
Current smoker (%)	2.07 (1.28–3.36)	<0.01	2.36 (1.44–3.89)	<0.01	1.93 (1.06–3.52)	0.03
Heavy drinker (%)	1.30 (0.91–1.84)	0.15	1.57 (1.08–2.27)	0.02	1.40 (0.91–2.16)	0.12
Married (%)	1.10 (0.81–1.50)	0.53	1.02 (0.74–1.41)	0.90	-	-
Education (% ≤ HS)	0.93 (0.68–1.28)	0.66	0.78 (0.56–1.09)	0.15	-	-
Employment (% full-time)	0.87 (0.63–1.19)	0.37	1.27 (0.87–1.87)	0.22	-	-
Income level (% ≥ $50,000)	1.11 (0.80–1.55)	0.53	1.15 (0.82–1.62)	0.42	-	-
Postmenopausal (%)	1.01 (0.55–1.84)	0.99	0.69 (0.35–1.33)	0.27	-	-
Diabetes (%)	2.01 (1.34–2.90)	<0.001	1.94 (1.33–2.83)	<0.01	2.07 (1.35–3.18)	<0.01
Hypercholesterolemia (%)	1.22 (0.88–1.71)	0.24	1.11 (0.78–1.56)	0.57	-	-
Antihypertensive medication (%)	1.88 (1.34–2.63)	<0.001	1.84 (1.27–2.66)	<0.01	1.61 (1.07–2.43)	0.02
Physical activity score	1.00 (0.94–1.06)	0.88	1.03 (0.96–1.10)	0.41	-	-
Total cholesterol (mg/dl)	1.00 (0.99–1.01)	0.38	1.00 (0.99–1.01)[a]	0.51	-	-
HDL cholesterol (mg/dl)	1.00 (0.99–1.01)	0.65	1.00 (0.99–1.02)	0.57	-	-
LDL cholesterol (mg/dl)	1.00 (0.99–1.01)	0.39	1.00 (1.00–1.01)	0.56	-	-
Triglycerides (mg/dl)	1.00 (0.99–1.00)	0.82	1.00 (0.99–1.00)	0.83	-	-
hsCRP (mg/dl)	1.04 (0.86–1.26)	0.69	1.10 (0.90–1.35)	0.36	-	-
Sodium excretion (mEq/24 h)	1.00 (0.99–1.00)	0.30	1.00 (0.99–1.01)	0.19	-	-
Potassium excretion (mEq/24 h)	1.00 (0.99–1.01)	0.93	1.00 (0.99–1.01)	0.79	-	-
Clinic BP (mm Hg)	-	<0.001	-	<0.001	-	<0.001
<100/70	ref	-	ref	-	ref	-
100–109/70–74	1.21 (0.36–4.04)	0.75	1.17 (0.34–3.94)	0.81	0.74 (0.20–2.70)	0.65
110–119/75–79	1.42 (0.46–4.37)	0.55	1.28 (0.41–4.02)	0.67	1.04 (0.32–3.34)	0.95
120–129/80–84	3.21 (1.07–9.60)	0.04	2.94 (0.97–8.93)	0.057	2.24 (0.71–7.01)	0.17
130–139/85–89	5.82 (1.94–17.45)	<0.01	5.52 (1.81–16.82)	<0.01	4.21 (1.33–13.36)	0.02

Model 1: Adjusted for age, gender, and body mass index. Model 2: Adjusted for covariates in model 1 plus all variables significantly associated with masked hypertension in univariate analyses.

Abbreviations: BP, blood pressure; CI, confidence interval; HDL, high-density lipoprotein; HS, high school; hsCRP, high-sensitivity C-reactive protein; LDL, low-density lipoprotein.

[a]Hosmer–Lemeshow goodness-of-fit: $P < 0.05$.

untreated adults from 7 European countries. The prevalence of masked hypertension in the PAMELA study, a population-based study in Italy, was also lower (8%) when masked hypertension was defined by 24-hour ABP ≥125/79 mm Hg.[24] Antihypertensive medication usage, however, was not reported, thus it is unclear how prevalence rates in the PAMELA study would compare when stratified according to antihypertensive medication treatment. From the reported prevalence rates in these studies it is apparent, although not strikingly, that African Americans in the JHS cohort have the highest prevalence rates among population-based studies published to date. Unfortunately, few studies have directly compared masked hypertension prevalence rates across racial/ethnic groups. Future studies in multiethnic samples in the United States may be warranted.

In previous studies that have reported on the prevalence of masked hypertension in all-African American populations, alarmingly high prevalence rates of 70% and 58% were reported among 691 African Americans with chronic kidney disease and among 58 putatively healthy African Americans with prehypertension, respectively.[25,26] In the current study, masked hypertension prevalence among participants with normal clinic BP (34%) was considerably less. There are 2 potential explanations for these differences. First, the chronic kidney disease and prehypertension inclusion criteria in the 2 previous studies likely inflated masked hypertension prevalence. Second, masked hypertension prevalence is largely dependent on its definition, thus use of different ABP limits undoubtedly will affect prevalence data. In the previous studies, masked hypertension was defined as either elevated

awake or sleep ABP. This is in contrast to the present study wherein masked hypertension was defined only by elevated awake ABP in accordance with international guidelines.[17,18] When we defined masked hypertension as either elevated awake or sleep ABP, masked hypertension prevalence among individuals with normal clinic BP approached that of previous studies (~55%).

Another important finding from our study was that masked hypertension prevalence was closely aligned with clinic BP. Whether ABPM should be introduced into clinical practice to screen for masked hypertension is a matter of considerable debate. It is not feasible and may be inappropriate to do ABPM on all patients. From our findings, it could be argued that a more feasible scenario would be to screen African Americans who present as prehypertensive. To narrow the focus more, JHS participants with stage 2 prehypertension had a 4-fold higher likelihood of masked hypertension. More careful screening among African Americans in the prehypertensive range may be particularly important as analysis of prehypertensives enrolled in the ARIC study showed a 3.29 higher risk of incident CVD among prehypertensive African Americans, most of whom were from Jackson, Mississippi, compared to normotensives, which exceeded previous findings from the Framingham Heart Study regarding the CVD risk conferred by prehypertension.[27,28] If ARIC participants had similar rates of masked hypertension as observed in the JHS cohort, this, in part, may explain the greater CVD risk among African Americans with prehypertension.

With respect to antihypertensive medication usage, the issue of masked hypertension in treated and untreated participants is somewhat different as screening is not an issue in people who have already been identified as hypertensive. Instead the issue lies in the fact that normal clinic BP may give rise to the false impression that BP is adequately controlled (e.g., masked uncontrolled hypertension). Previous work in the JHS has shown that control rates of hypertension among JHS participants were higher than in their African American counterparts from the National Health and Nutrition Examination Survey and similar to that of whites in National Health and Nutrition Examination Survey; leading investigators to speculate that hypertension control in African Americans may be better in the "stroke belt" compared with other parts of the country.[15] Although they reported that 66% of JHS participants with hypertension had controlled clinic BP, our findings suggest a number of those individuals had masked uncontrolled hypertensive (~39%). Notably, in the present analyses, treated participants had a 61% greater likelihood of having masked hypertension. Considering the disproportionate CVD burden in African Americans, these findings may further highlight the importance of assessing the control of hypertension outside of the clinic to help close the health disparity gap for African Americans.

The greater degree of TOD in masked hypertensives compared to sustained normotensives has been reported in many populations, and commonly, the degree of TOD has been reported to be similar to that of sustained hypertensives.[29] Our findings are in alignment with previous reports as indices of arterial, cardiac, and renal damage were all greater in masked hypertensives when compared to normotensives, and were similar to that of sustained hypertensives. These findings provide some of the first evidence that masked hypertension is associated with TOD in an African American population and could provide justification for the careful screening and diagnosis of hypertension in African Americans.

Several limitations must be noted when interpreting our findings. First, clinic BP measurements were obtained using a random-zero sphygmomanometer; a device that some studies have suggested may underestimate systolic and diastolic BP.[30] However, it has been reported that the underestimation of BP by this device are mainly due to observer variations in technique rather than intrinsic problems with equipment.[31] Thus, it has been suggested that the underestimation of BP by the random-zero sphygmomanometer can be minimized or eliminated when observer training is rigorous, technique is stringently monitored, and equipment is routinely maintenanced,[31,32] such as that in the JHS.[33] Second, only 2 clinic BP measurements were taken at only one visit. This may have affected the reliability of masked hypertension classification. It should be noted, however, that masked hypertension reproducibility has been reported to be fair-to-moderate when defined using a single office BP average.[34] Third, the JHS sample was designed to explore reasons for the racial disparity in hypertension and was not designed to function as a nationally representative sample. Thus, findings from the study might not be generalized to all African Americans. Fourth, the number of differences among included vs. excluded JHS participants for select demographic and clinical characteristics is reflective of a volunteer bias. Thus, our findings may also not be generalizable to the entire JHS cohort. Finally, because of the cross-sectional nature of our analyses, we cannot infer causality from the associations observed.

Despite these limitations, there are several strengths to our study. First, the JHS is the largest population-based study ever conducted among African Americans. This landmark study provided a unique and excellent opportunity to characterize in African Americans an important hypertension phenotype. Second, the subsample of JHS participants who conducted ABPM is one of the largest cohorts with ABPM in the United States. Finally, BP was measured by trained technicians using a standardized protocol that was stringently monitored.

In conclusion, in this population-based cohort of African Americans approximately one-third of participants with presumably normal clinic BP had undiagnosed or uncontrolled hypertension when assessed using ABPM. The prevalence of masked hypertension in this cohort from the JHS was higher than has been reported in other international population-based studies; suggestive that African Americans may have a higher prevalence of masked hypertension than other race/ethnicities. Future studies in multiethnic samples are needed to confirm this finding and determine whether more vigilant screening of BP in African Americans through out-of-office BP monitoring is warranted to reduce racial disparities in CVD.

SUPPLEMENTARY MATERIAL

Supplementary materials are available at *American Journal of Hypertension* (http://ajh.oxfordjournals.org).

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DISCLOSURE

The authors declared no conflict of interest.

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