Masked Hypertension

Masked Hypertension and Cardiovascular Disease Events in a Prospective Cohort of Blacks

The Jackson Heart Study

John N. Booth III, Keith M. Diaz, Samantha R. Seals, Mario Sims, Joseph Ravenell, Paul Muntner, Daichi Shimbo

Abstract—Masked hypertension, defined as nonelevated clinic blood pressure (BP) with elevated out-of-clinic BP, has been associated with increased cardiovascular disease (CVD) risk in Europeans and Asians. Few data are available on masked hypertension and CVD and mortality risk among blacks. We analyzed data from the Jackson Heart Study, a prospective cohort study of blacks. Analyses included participants with clinic-measured systolic/diastolic BP <140/90 mm Hg who completed ambulatory BP monitoring after the baseline examination in 2000 to 2004 (n=738). Masked daytime (10:00 AM–8:00 PM) hypertension was defined as mean ambulatory systolic/diastolic BP ≥135/85 mm Hg. Masked nighttime (midnight to 6:00 AM) hypertension was defined as mean ambulatory systolic/diastolic BP ≥120/70 mm Hg. Masked 24-hour hypertension was defined as mean systolic/diastolic BP ≥130/80 mm Hg. CVD events (nonfatal/fatal stroke, nonfatal myocardial infarction, or fatal coronary heart disease) and deaths identified through December 2010 were adjudicated. Any masked hypertension (masked daytime, nighttime, or 24-hour hypertension) was present in 52.2% of participants; 28.2%, 48.2% and 31.7% had masked daytime, nighttime, and 24-hour hypertension, respectively. There were 51 CVD events and 44 deaths during a median follow-up of 8.2 and 8.5 years, respectively. CVD rates per 1000 person-years (95% confidence interval) in participants with and without any masked hypertension were 13.5 (9.9–18.4) and 3.9 (2.2–7.1), respectively. The multivariable adjusted hazard ratio (95% confidence interval) for CVD was 2.49 (1.26–4.93) for any masked hypertension. The prevalence of masked hypertension has been reported to be 15% to 30% when defined by elevated daytime or 24-hour BP and as high as 60% when nighttime BP is included in the definition. A study of Europeans and Japanese participants have reported masked hypertension to be associated with increased risk for cardiovascular disease (CVD). Data are scarce on the prognostic significance of masked hypertension among blacks, a population with substantially higher risk for hypertension-related outcomes compared with whites. Studying masked hypertension in blacks may be particularly important as a high prevalence in this population would indicate the need to identify out-of-office hypertension and poorly controlled BP. Using data from the Jackson Heart Study (JHS), a large cohort comprised exclusively...

Key Words: African American ■ ambulatory blood pressure monitoring ■ black ■ blood pressure ■ cardiovascular disease ■ hypertension ■ masked hypertension

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blacks, we determined the prevalence of masked hypertension and its association with CVD events and all-cause mortality. Additionally, we evaluated whether this association differed when defining masked hypertension using daytime BP, nighttime BP, or 24-hour BP.

Methods

Study Population

The JHS, a population-based prospective cohort study, was designed to evaluate CVD risk among blacks (https://www.jacksonheart-study.org/jhsinfo/). Briefly, the JHS enrolled 5301 noninstitutionalized blacks, aged ≥21 years, between 2000 and 2004 from the Atherosclerosis Risk in the Community site in Jackson, Mississippi, and a representative sample of urban and rural Jackson, Mississippi metropolitan tricounty (Hinds, Madison, and Rankin counties) residents, volunteers, randomly contacted individuals, and secondary family members. The current analysis was restricted to JHS participants who underwent ABPM after the baseline examination (n=1148). Participants who did not meet the International Database on ABPM in relation to Cardiovascular Outcomes criteria for a complete ABPM (n=102; described below) or were missing clinic-measured BP (n=5) or information on antihypertensive medication use (n=58) were excluded. Because masked hypertension can only be present among individuals without elevated clinic BP, we excluded participants with SBP ≥140 mm Hg or DBP ≥90 mm Hg during the baseline study clinic visit (n=245), leaving 738 participants for the current analyses. The institutional review board governing human subjects’ research approved the JHS protocol and current analysis. All participants provided written informed consent.

Data Collection

Data were collected during an in-home interview, clinic examination, and through ABPM. During the in-home interview, trained staff administered questionnaires to collect self-reported information on sociodemographics, health behaviors, previous diagnosed comorbid conditions, snoring and breathing cessation during sleep, and daytime tiredness. During the clinic examination, trained technicians measured height, weight, neck circumference, and BP; collected blood samples; and recorded the names of prescription and over-the-counter medications taken in the 2 weeks before the study visit. After the clinic examination, participants were given the opportunity to complete ABPM.

Using a modified Baecke questionnaire, the duration, frequency, and intensity of physical activity during active living, work, home life, and sport were recorded and summed to calculate a total physical activity score. Higher scores represent more daily physical activity. Current smoking was defined by affirmative responses to the questions “Have you smoked >400 cigarettes in your lifetime?” and “Do you now smoke cigarettes?” Body mass index was calculated as weight in kilograms divided by height in meters squared. Antihypertensive medication use and history of myocardial infarction (MI) and stroke were self-reported. Total and high-density lipoprotein cholesterol were quantified by an oxidase method. High-sensitivity C-reactive protein was calculated using the latex particle immunoturbidimetric assay method. The use of statins was determined by pill bottle review. Urinary albumin and creatinine were quantified from a 24-hour urine collection or from a spot urine sample using the nephelometric immunoassay and enzymatic methods, respectively. Albuminuria was defined as a urinary albumin/urinary creatinine ratio ≥30 mg/g. Estimated glomerular filtration rate was calculated using the Chronic Kidney Disease Epidemiology Collaboration equation. Reduced estimated glomerular filtration rate was defined as <60 mL/min/1.73 m². Diabetes mellitus was defined as a fasting (≥8 hours) serum glucose ≥126 mg/dL or hemoglobin A1c ≥6.5% or use of insulin or oral hypoglycemic medications within 2 weeks before the clinic examination. Sleep apnea risk was calculated using available components that comprise the validated STOP-BANG screening tool, which identifies individuals with a high risk for sleep apnea. There are 8 components that assess the following attributes: snoring loudly, breathing cessation during sleep, tiredness during the daytime, hypertension status (ie, mean clinic SBP ≥140 mm Hg or DBP ≥90 mm Hg or self-reported use of antihypertensive medication), body mass index ≥35 kg/m², being aged ≥50 years, having a neck circumference >40 cm, and being male. Individuals with ≥3 attributes described above are categorized as high risk for obstructive sleep apnea.

Clinic-measured BP was obtained following a standardized protocol. Participants were asked to avoid caffeine, eating, heavy physical activity, and smoking and alcohol intake for 12 hours before the visit. After participants had sat for at least 5 minutes in an upright position with their back and arms supported, feet flat on the floor, and legs uncrossed, trained staff conducted 2 BP measurements in the right arm. One minute elapsed between the 2 measurements. A random zero sphygmomanometer (Hawksley and Sons, Ltd) and appropriate cuff size, determined from an arm circumference measurement, was used. The JHS Coordinating Center conducted quality control by monitoring digit preference for each technician and by comparing mean BP measurements within and between trained technicians. The 2 clinic-measured BP measurements were averaged for analysis. Nonelevated clinic-measured BP was defined as a mean clinic SBP <140 mm Hg and DBP <90 mm Hg.

Ambulatory Blood Pressure Monitoring

After the baseline examination, participants were fitted with an ABPM device (Spacelabs 90207) on their nondominant arm. Ambulatory BP was recorded every 20 minutes. After 24 hours, participants returned to the clinic, and the device was removed. Data were evaluated for quality and processed with Medifacts International’s Medicom software (Rockville, MD). International Database on ABPM in relation to Cardiovascular Outcomes criteria were used to define whether the ABPM measurement was complete. Specifically, participants were considered to have a complete ABPM if they had ≥210 daytime (10:00 AM–8:00 PM) and ≥25 nighttime (midnight to 6:00 AM) SBP and DBP measurements. Daytime hypertension was defined as a mean SBP ≥135 mm Hg or mean DBP ≥85 mm Hg based on measurements between 10:00 AM and 8:00 PM. Nighttime hypertension was defined as a mean SBP ≥120 mm Hg or mean DBP ≥70 mm Hg based on measurements between midnight and 6:00 AM, and 24-hour hypertension was defined as mean SBP ≥130 mm Hg or mean DBP ≥80 mm Hg using all available BP measurements from ABPM. Because the current analysis was restricted to participants with nonelevated clinic-measured BP, those with daytime, nighttime, and 24-hour hypertension were categorized as having masked daytime, masked nighttime, and masked 24-hour hypertension, respectively. Additionally, participants with masked daytime, nighttime, or 24-hour hypertension were categorized as having any masked hypertension. Nondipping BP status, defined as mean nighttime to daytime SBP ratio >90%, was also determined for each participant.

Outcomes

The primary outcome was CVD events. All-cause mortality was examined as a secondary outcome. Adjudication procedures for these outcomes have been described previously. Briefly, living participants or their proxies were contacted annually via telephone to assess potential CVD events and vital status. Hospital discharge lists with specific diagnosis criteria were also obtained from the Jackson, Mississippi, tricounty area hospitals. Death certificates were requested from the Mississippi State Department of Health for JHS participants as needed. When a CVD-related hospitalization or a death was identified, medical records were retrieved and abstracted. Trained clinicians adjudicated events following published guidelines using the information available about the circumstance surrounding an event. For the current analysis, definite or probable CVD events (ie, coronary heart disease, nonfatal MI, or acute coronary heart disease death or stroke defined as noncarotid embolic or thrombotic brain infarction, brain hemorrhage, or subarachnoid hemorrhage) and all-cause mortality were available through December 31, 2010.

Regression analysis was performed using SAS software (Version 9.4, Cary, NC). All estimates were age-adjusted using the direct method and the standard United States population as the reference. Covariates included age, gender, race, body mass index, smoking status, antihypertensive medication use, estimated glomerular filtration rate, diabetes mellitus, and hypertension status (mean clinic SBP ≥140 mm Hg or DBP ≥90 mm Hg or self-reported use of antihypertensive medication). Separate regression models were performed for each BP measurement (daytime, nighttime, 24-hour), and all models were adjusted for antihypertensive medication use and diabetes mellitus. Mean clinic BMIs were ≥35 kg/m², being aged ≥50 years, having a neck circumference >40 cm, and being male.
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The funding source had no role in the study design, collection, analysis, interpretation, or drafting of the article or in the decision to submit the article for publication.

Statistical Analysis
Characteristics were calculated for participants with and without any masked hypertension. The prevalence of any masked hypertension and masked daytime, nighttime, or 24-hour hypertension was calculated, overall, and for participants taking and not taking antihypertensive medication, separately.

The incidence rates of CVD were calculated for participants with and without daytime, nighttime, 24-hour, and any masked hypertension. Using Cox proportional hazards regression, the hazard ratios (HR) and 95% confidence intervals (CI) for CVD associated with masked daytime, nighttime, and 24-hour hypertension, and any masked hypertension were calculated. HRs were calculated after age and sex adjustment (Model 1) and after additional adjustment for clinic-measured SBP and DBP and antihypertensive medication use (Model 2) and a CVD risk score (Model 3). Risk scores are a useful approach for controlling for confounders when there are a limited number of outcomes.\(^2\) The CVD risk score was created in the full JHS population with clinic-measured SBP <140 mm Hg and DBP <90 mm Hg (n=3797 and 201 incident CVD events) by determining the 10-year predicted probabilities for CVD from a Cox regression model with age, sex, education, smoking status, physical activity, body mass index, history of MI and stroke, diabetes mellitus, total and high-density lipoprotein cholesterol, C-reactive protein, statin use, reduced estimated glomerular filtration rate, albuminuria, and use antihypertensive medication use as independent variables. To account for variables in the CVD risk score with missing data (Table S1 in the online-only Data Supplement), multiple imputation was performed using chained equations and 10 data sets.\(^2\) Two additional models included adjustment for the variables in Model 3 plus nondipping BP status (Model 4) and, separately, adjustment for high sleep apnea risk (Model 5). Analyses were repeated in subgroups defined by antihypertensive medication use and, separately, after restricting the analytic sample to participants without a history of MI or stroke at the baseline examination.

Participants were then divided into tertiles based on the distribution of daytime, 24-hour, and nighttime SBP and, separately, DBP. CVD incidence rates were calculated by tertile of each BP measure and the HRs for CVD associated with the upper 2 tertiles, separately, compared with the lowest tertile of each BP measure. Next, the HRs for outcomes associated with daytime, nighttime, and 24-hour SBP and DBP modeled as continuous variables, expressed per SD higher level, were calculated in all participants and subgroups defined by antihypertensive medication use. Five levels of adjustment were performed as described above.

Using all-cause mortality as a secondary outcome, the above analyses were repeated. A mortality risk score was created in the full JHS population with clinic-measured SBP <140 mm Hg and DBP <90 mm Hg (n=3797 with n=282 deaths) and included as a covariate in Model 3. Similar to the analysis for CVD events, 2 additional models adjusted for the variables in Model 3 plus nondipping BP status (Model 4) and, separately, for high sleep apnea risk (Model 5). P values <0.05 were considered statistically significant. All data analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC) or Stata version 13.1 (Stata, Inc, College Station, TX).

Results
Participant Characteristics
Compared to participants without masked daytime, nighttime, or 24-hour hypertension, those with any masked hypertension were older, more likely to be male and have less than a high school education, smoke cigarettes, have diabetes mellitus, a reduced eGFR (estimated glomerular filtration rate) and albuminuria, and use antihypertensive medication (Table 1). Participants with any masked hypertension also had a higher predicted 10-year CVD risk score and clinic and ambulatory BP levels.

Overall, 52.2% of participants with nonelevated clinic-measured BP had any masked hypertension (Figure). Any masked hypertension and masked daytime, nighttime, and 24-hour hypertension were each more common among participants taking versus not taking antihypertensive medication. Masked nighttime hypertension was the most common type of masked hypertension followed by masked 24-hour and daytime hypertension, respectively.

Masked Hypertension and CVD
During a median follow-up of 8.2 years (maximum: 10.2 years), there were 51 CVD events (13 events among participants not taking antihypertensive medication and 38 events among participants taking antihypertensive medication). CVD incidence rates were higher among participants with compared with participants without any masked hypertension and masked daytime, nighttime, and 24-hour hypertension, separately (Table 2, overall). Any masked hypertension and each type of masked hypertension was associated with increased CVD risk after further adjustment for the variables in Model 3, Model 4, and Model 5. Each type of masked hypertension was associated with CVD incidence among participants taking antihypertensive medication (Table 2, taking antihypertensive medication). In those not taking antihypertensive medication, any masked hypertension and each type of masked hypertension were associated with higher incidence of CVD, but only masked 24-hour hypertension was associated with CVD risk after multivariable adjustment (Table 2, not taking antihypertensive medication). Among participants without a history of CVD at baseline, CVD incidence rates were higher in those with versus without any masked hypertension and each type of masked hypertension (Table S2). After further adjustment for CVD risk score in Model 3, the HR for CVD was 2.05 (95% CI, 0.99–4.28), 2.30 (95% CI, 1.23–4.28), 1.89 (95% CI, 0.94–3.78), and 1.73 (95% CI, 0.90–3.32) for those with any, daytime, nighttime, and 24-hour masked hypertension, respectively. The results were similar after further adjustment for nondipping BP status (Model 4) and having high risk for sleep apnea (Model 5).

Ambulatory Blood Pressure and CVD
Higher tertiles of daytime, nighttime, and 24-hour SBP were associated with increased CVD risk, before and after multivariable adjustment (Table 3, systolic blood pressure). The highest tertile of daytime, nighttime, and 24-hour DBP were associated with increased CVD incidence rates and after age and sex adjustment (Table 3, diastolic blood pressure). After further multivariable adjustment, daytime but not nighttime or 24-hour DBP was associated with increased CVD risk.

Modeled as continuous variables, daytime, nighttime, and 24-hour SBP and DBP were associated with increased CVD risk, in the overall population and among participants taking antihypertensive medication (Table S3, panel A for SBP and panel B for DBP). Among participants not taking antihypertensive medication, daytime, nighttime, and 24-hour SBP and DBP were associated with CVD risk after age and sex adjustment.
adjustment. After further multivariable adjustment, only higher nighttime DBP was associated with an increased CVD risk.

### Masked Hypertension and All-Cause Mortality

During a median follow-up of 8.5 years (maximum: 10.2 years), there were 44 deaths (28 and 16 deaths among participants taking and not taking antihypertensive medication, respectively). All-cause mortality rates were higher among participants with versus without masked hypertension (Table S4). Masked hypertension (any, and for daytime, nighttime, and 24-hour, separately) was not associated with all-cause mortality after age and sex adjustment or further multivariable adjustment in the overall sample and in those taking and not taking antihypertensive medication evaluated separately.

### Discussion

In this population-based sample of blacks without elevated clinic-measured BP, the prevalence of masked hypertension
was high. Masked hypertension, regardless of whether it was defined using daytime, nighttime, or 24-hour BP, was associated with an increased risk for CVD. These associations were present in the overall population, among participants taking and not taking antihypertensive medication, and in those without history of CVD at baseline. Higher tertiles of daytime, nighttime, and 24-hour SBP were associated with an increased risk for CVD events. Also, high daytime DBP was associated with increased risk for CVD events. In contrast, masked hypertension was not associated with all-cause mortality.

Several large European, Asian, and South American population-based studies (>500 participants) have previously examined the prevalence of masked hypertension among those with nonelevated clinic BP (Table 4). Most of these studies reported the prevalence of masked daytime hypertension, whereas fewer studies reported the prevalence of masked nighttime or 24-hour hypertension. Furthermore, few studies examined the prevalence of masked hypertension stratified by antihypertensive medication use. Overall, the prevalence of any masked hypertension and masked daytime, nighttime, and 24-hour hypertension was higher in the current study compared with European, Asian, and South American populations.

Previous studies of masked hypertension on CVD outcomes have had limited representation of blacks, and no population-based studies included blacks. Two small studies (each <100 participants), which included middle-aged blacks, have reported a prevalence of masked hypertension exceeding 40%. Also, in the African American Study of Kidney Disease Cohort Study, which included 691 blacks with established kidney disease, 70% of participants had masked daytime or nighttime hypertension. In the current study, ∼30% of blacks had masked daytime and 24-hour hypertension. Furthermore, >50% of participants had any masked hypertension or nighttime hypertension.

One important issue is whether the thresholds for masked daytime and nighttime hypertension and 24-hour hypertension are relevant for blacks. Although the SBP/DBP thresholds used in the current study (daytime: ≥135/85 mm Hg, nighttime: ≥120/70 mm Hg, and 24-hour: ≥130/80 mm Hg) are present in several guidelines and position papers, these thresholds were derived in European, Asian, and South American samples. Future studies should determine ambulatory BP thresholds in blacks.

In studies primarily from Europe, Asia, and South America, masked hypertension has been reported to be associated with an increased risk for CVD outcomes overall and in adults taking and not taking antihypertensive medications. A meta-analysis of 7961 adults from 7 studies estimated the risk for CVD (ie, MI, stroke, and peripheral vascular events) to be 2.09 (95% CI, 1.55–2.81) times higher in those with masked daytime hypertension compared with normotensive adults. Among 2024 Pressioni Arteriose Monitorate e Loro Associazioni study participants aged 25 to 74 years without elevated clinic-measured BP, the HR was 2.75 (95% CI, 1.07–7.09) comparing masked 24-hour hypertension with clinic-measured SBP/DBP <120/80 mm Hg. In the current study, we extend previous studies by reporting a strong association between masked hypertension and CVD in blacks. Furthermore, these results were consistent across higher tertiles of ambulatory BP.

The association between masked hypertension and all-cause mortality has been investigated previously. The HR (95% CI) for mortality associated with masked daytime hypertension was 1.23 (0.99–1.51) and with masked 24-hour hypertension was 1.25 (0.99–1.56) in a pooled cohort of 12 population-based studies including 8237 participants not taking antihypertensive medication. Additionally, the HR (95% CI) for the association between masked nighttime hypertension and death was 1.29 (1.04–1.59). Data on this association in blacks are limited. Reported herein, the HR ranged from 1.15 (any masked hypertension) to 1.38 (masked 24-hour hypertension), but it was not statistically significant. However, the association between masked hypertension and mortality in blacks needs further investigation because few deaths occurred during follow-up.

There is ongoing debate about whether home BP monitoring or ABPM is more useful for assessing CVD risk. The high prevalence of masked nighttime hypertension along with the magnitude of the HR for CVD events associated with this phenotype in the current study supports the use of ABPM because home BP monitoring is unable to assess nighttime BP. The presence of an association in participants taking antihypertensive medication suggests that ABPM may also be useful for targeting treatment to achieve normal ambulatory BP.
Table 2. Incidence Rates and Hazard Ratios for Cardiovascular Disease Associated With Any Masked Hypertension and Masked Daytime, Nighttime, 24-h Hypertension Among Jackson Heart Study Participants With Nonelevated Clinic-Measured Blood Pressure (Overall and by Antihypertensive Medication Use)

<table>
<thead>
<tr>
<th>Masked Hypertension Status</th>
<th>Events/n at Risk</th>
<th>Incidence Rate (95% CI)*</th>
<th>Hazard Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any masked hypertension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>11/353</td>
<td>3.9 (2.2–7.1)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>40/385</td>
<td>13.5 (9.9–18.4)</td>
<td>2.75 (1.40–5.40)</td>
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<td>Masked daytime hypertension</td>
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<tr>
<td>No</td>
<td>22/530</td>
<td>5.3 (3.5–8.0)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>29/208</td>
<td>18.3 (12.7–26.3)</td>
<td>2.83 (1.62–4.94)</td>
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<td>Masked nighttime hypertension</td>
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<tr>
<td>No</td>
<td>13/382</td>
<td>4.3 (2.5–7.4)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>38/356</td>
<td>13.9 (10.1–19.1)</td>
<td>2.61 (1.38–4.94)</td>
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<td>Masked 24-h hypertension</td>
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<td></td>
</tr>
<tr>
<td>No</td>
<td>20/504</td>
<td>5.0 (3.2–7.8)</td>
<td>1 (ref)</td>
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<td>Yes</td>
<td>31/234</td>
<td>17.4 (12.3–24.8)</td>
<td>2.70 (1.53–4.77)</td>
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<td>Taking antihypertensive medication (n=407)</td>
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<td></td>
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<td>Any masked hypertension</td>
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<td></td>
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<td>No</td>
<td>7/168</td>
<td>5.2 (2.5–10.9)</td>
<td>1 (ref)</td>
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<td>Yes</td>
<td>31/239</td>
<td>16.8 (11.8–23.8)</td>
<td>2.09 (0.63–6.90)</td>
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<td>Masked daytime hypertension</td>
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<td>16/272</td>
<td>7.4 (4.6–12.1)</td>
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<td>Yes</td>
<td>22/135</td>
<td>21.1 (13.9–32.1)</td>
<td>2.68 (0.87–8.32)</td>
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<td>Masked nighttime hypertension</td>
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<td>No</td>
<td>9/189</td>
<td>6.0 (3.1–11.4)</td>
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<td>29/218</td>
<td>17.3 (12.0–24.9)</td>
<td>2.32 (0.70–7.67)</td>
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<td>23/146</td>
<td>20.6 (13.7–30.9)</td>
<td>3.14 (1.01–9.77)</td>
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<td>Not taking antihypertensive medication (n=331)</td>
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<td>Any masked hypertension</td>
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<tr>
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<td>4/185</td>
<td>2.8 (1.0–7.3)</td>
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<td>8.0 (4.2–15.4)</td>
<td>2.91 (1.27–6.67)</td>
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<td>6/258</td>
<td>3.0 (1.3–6.6)</td>
<td>1 (ref)</td>
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<td>Yes</td>
<td>7/73</td>
<td>12.8 (6.1–26.9)</td>
<td>2.74 (1.44–5.25)</td>
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<td>Masked nighttime hypertension</td>
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<tr>
<td>No</td>
<td>4/193</td>
<td>2.6 (1.0–7.0)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>9/138</td>
<td>8.5 (4.4–16.4)</td>
<td>2.58 (1.21–5.51)</td>
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<td>Masked 24-h hypertension</td>
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<tr>
<td>No</td>
<td>5/243</td>
<td>2.6 (1.1–6.3)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>8/88</td>
<td>12.2 (6.1–24.3)</td>
<td>2.43 (1.25–4.73)</td>
</tr>
</tbody>
</table>

Any masked hypertension: the presence of daytime hypertension, nighttime hypertension, or 24-h hypertension. Masked daytime hypertension: mean daytime systolic or diastolic ambulatory blood pressure ≥135 or ≥85 mm Hg. Masked nighttime hypertension: mean nighttime systolic or diastolic ambulatory blood pressure ≥120 or ≥70 mm Hg. Masked 24-h hypertension: mean 24-h systolic or diastolic ambulatory blood pressure ≥130 or ≥80 mm Hg. Model 1: adjustment for age and sex. Model 2: adjustment for age, sex, clinic systolic blood pressure, and clinic diastolic blood pressure. Model 3: adjustment for variables in Model 2 and the 10-y cardiovascular disease risk score. Model 4: adjustment for variables in Model 3 and nocturnal non-dipping blood pressure status. Model 5: adjustment for variables in Model 3 and the sleep apnea risk status. CI indicates confidence interval.

*Crude incidence rate per 1000 person-years (95% CI).
As such, ABPM provides an opportunity to identify, treat, and control masked hypertension in blacks and may help to reduce racial disparities in CVD.

Published recommendations for using ABPM in the clinic setting are available, but few mention using ABPM to identify masked hypertension.2–5 The Canadian Education Program in Hypertension recommends assessment with ABPM in adults without macrovascular target-organ damage, diabetes mellitus, or chronic kidney disease when SBP is between 140 and 180 mm Hg or DBP is between 90 and 110 mm Hg during 2 consecutive clinic visits. The US Preventive Services Task Force recommends using ABPM to confirm a clinic-measured

Table 3. Incidence Rates and Hazard Ratios for Cardiovascular Disease Associated With Tertile of Daytime, Nighttime, or 24-h Systolic and Diastolic Ambulatory Blood Pressure Among Jackson Heart Study Participants With Nonelevated Clinic-Measured Blood Pressure (n=738)

<table>
<thead>
<tr>
<th>Tertile of Blood Pressure</th>
<th>Incidence Rate (95% CI)*</th>
<th>Hazard Ratio (95% CI) Model 1</th>
<th>Hazard Ratio (95% CI) Model 2</th>
<th>Hazard Ratio (95% CI) Model 3</th>
<th>Hazard Ratio (95% CI) Model 4</th>
<th>Hazard Ratio (95% CI) Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile of daytime SBP, mm Hg</td>
<td>12/246</td>
<td>4.1 (2.0–8.1)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
</tr>
<tr>
<td>≥131.0 31/246</td>
<td>16.6 (11.7–23.6)</td>
<td>2.66 (1.21–5.87)</td>
<td>2.73 (1.20–6.22)</td>
<td>2.35 (1.01–5.46)</td>
<td>2.70 (1.16–6.30)</td>
<td>2.38 (1.02–5.53)</td>
</tr>
<tr>
<td>*P trend ... &lt;0.001</td>
<td>0.004</td>
<td>0.005</td>
<td>0.011</td>
<td>0.005</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>Tertile of nighttime SBP, mm Hg</td>
<td>14/245</td>
<td>7.4 (4.4–12.5)</td>
<td>1.93 (0.74–5.06)</td>
<td>1.93 (0.73–5.11)</td>
<td>1.73 (0.65–4.60)</td>
<td>1.51 (0.56–4.11)</td>
</tr>
<tr>
<td>≥122.8 31/242</td>
<td>16.7 (11.8–23.8)</td>
<td>3.46 (1.42–8.42)</td>
<td>3.41 (1.36–8.56)</td>
<td>2.97 (1.18–7.52)</td>
<td>2.38 (0.89–6.38)</td>
<td>3.11 (1.22–7.92)</td>
</tr>
<tr>
<td>*P trend ... &lt;0.001</td>
<td>0.003</td>
<td>0.004</td>
<td>0.011</td>
<td>0.056</td>
<td>0.046</td>
<td></td>
</tr>
<tr>
<td>Tertile of 24-h SBP, mm Hg</td>
<td>13/245</td>
<td>7.4 (4.4–12.5)</td>
<td>2.26 (0.81–6.31)</td>
<td>2.36 (0.83–6.70)</td>
<td>2.13 (0.74–6.11)</td>
<td>2.12 (0.74–6.03)</td>
</tr>
<tr>
<td>≥172.9 32/242</td>
<td>17.7 (12.5–25.0)</td>
<td>4.64 (1.78–12.09)</td>
<td>4.51 (1.66–12.30)</td>
<td>4.27 (1.58–11.60)</td>
<td>4.74 (1.74–12.9)</td>
<td></td>
</tr>
<tr>
<td>*P trend ... &lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile of daytime DBP, mm Hg</td>
<td>13/245</td>
<td>5.1 (2.7–9.4)</td>
<td>0.83 (0.37–1.84)</td>
<td>0.83 (0.37–1.85)</td>
<td>0.72 (0.32–1.61)</td>
<td>0.76 (0.33–1.72)</td>
</tr>
<tr>
<td>≥80.0 25/242</td>
<td>13.5 (9.1–19.9)</td>
<td>2.32 (1.21–4.46)</td>
<td>2.23 (1.13–4.38)</td>
<td>2.17 (1.10–4.28)</td>
<td>2.39 (1.22–4.71)</td>
<td>2.10 (1.07–4.15)</td>
</tr>
<tr>
<td>*P trend ... &lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>0.008</td>
<td>0.024</td>
<td></td>
</tr>
<tr>
<td>Tertile of nighttime DBP, mm Hg</td>
<td>15/244</td>
<td>7.9 (4.7–13.0)</td>
<td>1.35 (0.64–2.86)</td>
<td>1.33 (0.62–2.85)</td>
<td>1.24 (0.58–2.67)</td>
<td>1.03 (0.47–2.27)</td>
</tr>
<tr>
<td>≥70.5 23/243</td>
<td>12.3 (8.2–18.6)</td>
<td>2.06 (1.01–4.19)</td>
<td>1.95 (0.93–4.07)</td>
<td>1.78 (0.85–3.72)</td>
<td>1.33 (0.60–2.96)</td>
<td>1.73 (0.83–3.64)</td>
</tr>
<tr>
<td>*P trend ... &lt;0.001</td>
<td>0.003</td>
<td>0.016</td>
<td>0.019</td>
<td>0.008</td>
<td>0.024</td>
<td></td>
</tr>
<tr>
<td>Tertile of 24-h DBP, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SBP ≥140 mm Hg or DBP ≥90 mm Hg to prevent misdiagnosing and overtreating adults with isolated clinic hypertension.\textsuperscript{39} The United Kingdom National Institute for Health and Care Excellence guidelines recommend ABPM in adults with a clinic-measured SBP ≥140 mm Hg or DBP ≥90 mm Hg to confirm clinic-diagnosed hypertension.\textsuperscript{3} The 2013 European Society of Hypertension/European Society of Cardiology position paper on ABPM recommends performing ABPM when masked daytime or nighttime hypertension is suspected.\textsuperscript{5} However, this position paper does not clearly define which populations should be screened with ABPM to detect masked hypertension.\textsuperscript{5}

Empirical data on which populations should be screened with ABPM to detect masked hypertension are limited. There are several possible screening approaches: (1) use ABPM in all adults with nonelevated clinic-measured BP, (2) offer ABPM to adults with BP levels in the prehypertension range (ie, clinic-measured SBP/DBP 120–139/80–89 mm Hg) because of the substantial overlap that exists between prehypertension and masked hypertension,\textsuperscript{40,41} (3) screen adults with clinic-measured BP in the upper range of prehypertension (ie, clinic SBP 130–139 mm Hg or clinic DBP 85–89 mm Hg) because the prevalence of masked hypertension is very high in this range,\textsuperscript{9,40,42} and (4) use a prediction equation that incorporates clinic-measured BP and other/clinical characteristics to identify those with a higher probability of having masked hypertension.\textsuperscript{43} These approaches were compared by Booth et al\textsuperscript{43} who calculated test characteristics (ie, sensitivity, specificity, and positive and negative predictive values) and estimated the number of US adults who were not taking antihypertensive medications that would need to be screened with ABPM. The results indicated that screening all adults with clinic-measured BP in the prehypertension range may provide the most efficient approach (sensitivity: 82.5%; specificity: 61.5%).\textsuperscript{43}

The current study has several strengths. The JHS is among the few population-based investigations that have performed ABPM in blacks. Additionally, ABPM and clinic-measured BP were conducted following standardized protocols. JHS had a broad scope of data collection, which allowed us to control for several potential confounders. Also, the JHS actively followed up participants to identify CVD events and all-cause mortality, which were subsequently adjudicated following a standardized approach. Furthermore, the study was able to examine the contributions of daytime BP, nighttime BP, and separately 24-hour BP to CVD risk and mortality. Despite these strengths, several limitations should be considered when interpreting the results from the current analysis. ABPM was only conducted in a subset of JHS participants. Differences were present in demographic and clinical characteristics of JHS participants who volunteered those who did not volunteer to complete ABPM.\textsuperscript{9} Also, only a limited number of CVD events and deaths occurred. Despite few events occurring, we were able to control for multiple confounders using a risk score.

**Perspectives**

In the current study, masked hypertension was common among blacks without elevated clinic-measured BP. The prevalence of
any masked hypertension exceeded 50% and masked hypertension was associated with an increased risk for CVD events. This association was consistent for daytime, nighttime, and 24-hour masked hypertension. The results herein highlight the potential importance of assessing out-of-clinic BP during a 24-hour period among individuals with non-elevated clinic-measured BP.

Sources of Funding

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Disclosures

P. Muntner received an institutional grant from Amgen, Inc, unrelated to the topic of the current article. The other authors report no conflicts.

References

29. Hansen TW, Jeppesen J, Rasmussen S, Ibsen H, Torp-Pedersen C. Ambulatory blood pressure monitoring and risk of cardiovascular disease:
What Is New?

- Although masked hypertension has been associated with increased risk for cardiovascular disease (CVD) events in European and Japanese population-based samples, there are no published outcome data in blacks, a population with high CVD risk.
- There are few published data on the associations of masked nighttime and 24-hour hypertension with CVD events.

What Is Relevant?

- The prevalence of any masked hypertension exceeded 50% among blacks.

Novelty and Significance

- Nearly 50% of blacks with any masked hypertension had masked nighttime hypertension, which was the most common subtype.
- There was a strong association of masked daytime, nighttime, and 24-hour hypertension and any masked hypertension with CVD events in blacks.

Summary

Clinic-measured blood pressure may be inadequate for identifying many blacks with increased blood pressure–related CVD risk. The results reported herein suggest the potential importance of using ABPM for CVD risk stratification in blacks with nonelevated clinic BP.
Masked Hypertension and Cardiovascular Disease Events in a Prospective Cohort of Blacks: The Jackson Heart Study

John N. Booth III, Keith M. Diaz, Samantha R. Seals, Mario Sims, Joseph Ravenell, Paul Muntner and Daichi Shimbo

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Masked Hypertension and Cardiovascular Disease Events in a Prospective Cohort of African Americans: the Jackson Heart Study

Short title: Masked Hypertension and Outcomes

John N. Booth, III\textsuperscript{a}, MS, Keith M. Diaz\textsuperscript{b}, PhD, Samantha Seals\textsuperscript{c}, PhD, Mario Sims\textsuperscript{c}, PhD, Joseph Ravenell\textsuperscript{d}, MD, Paul Muntner\textsuperscript{a}, PhD, Daichi Shimbo\textsuperscript{b}, MD

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\textsuperscript{b}Columbia University Medical Center, New York, New York
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ds2231@columbia.edu
SUPPLEMENTAL MATERIAL:

Table S1. Percentage of missing data among Jackson Heart Study participants with non-elevated clinic-measured blood pressure (n=738).

Table S2. Incidence rates and hazard ratios for cardiovascular disease associated with any masked hypertension and masked daytime, nighttime and 24-hour hypertension among Jackson Heart Study participants with non-elevated clinic-measured blood pressure and without a history of myocardial infarction or stroke (n=681).

Table S3. Hazard ratio for cardiovascular disease events associated with one standard deviation higher daytime, nighttime and 24-hour systolic (Panel A) and diastolic (Panel B) ambulatory blood pressure among Jackson Heart Study participants with non-elevated clinic-measured blood pressure.

Table S4. Mortality rates and hazard ratios for all-cause mortality associated with any masked hypertension and masked daytime, nighttime and 24-hour hypertension among Jackson Heart Study participants with non-elevated clinic-measured blood pressure overall (Panel A) and by antihypertensive medication use (Panels B and C).
Table S1. Percentage of missing data among Jackson Heart Study participants with non-elevated clinic-measured blood pressure (n=738).

<table>
<thead>
<tr>
<th>Participant characteristics</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Sex</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Less than high school education</td>
<td>3 (0.4%)</td>
</tr>
<tr>
<td>Smoking status</td>
<td>5 (0.7%)</td>
</tr>
<tr>
<td>Physical activity</td>
<td>57 (7.7%)</td>
</tr>
<tr>
<td>Body mass index</td>
<td>1 (0.1%)</td>
</tr>
<tr>
<td>History of myocardial infarction</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>History of stroke</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Sleep apnea risk score</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Statin medication use</td>
<td>68 (9.2%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>6 (0.8%)</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>58 (7.9%)</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>58 (7.9%)</td>
</tr>
<tr>
<td>High-sensitivity c-reactive protein</td>
<td>8 (1.1%)</td>
</tr>
<tr>
<td>Estimate glomerular filtration rate</td>
<td>9 (1.2%)</td>
</tr>
<tr>
<td>Albumin-to-creatinine ratio</td>
<td>166 (22.5%)</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Antihypertensive medication use</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Nocturnal non-dipping</td>
<td>4 (0.5%)</td>
</tr>
</tbody>
</table>

Missing data were imputed for the development of cardiovascular disease and mortality risk scores as described in the methods.
Table S2. Incidence rates and hazard ratios for cardiovascular disease associated with any masked hypertension and masked daytime, nighttime and 24-hour hypertension among Jackson Heart Study participants with non-elevated clinic-measured blood pressure and without a history of myocardial infarction or stroke (n=681).

Population without a history of myocardial infarction or stroke

<table>
<thead>
<tr>
<th>Masked hypertension status</th>
<th>Events / n at risk</th>
<th>Incidence rate (95% CI)*</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any masked hypertension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>10 / 329</td>
<td>3.8 (2.1 - 7.1)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
</tr>
<tr>
<td>Yes</td>
<td>35 / 352</td>
<td>12.8 (9.2 - 17.9)</td>
<td>2.45 (1.20 - 4.99)</td>
<td>2.29 (1.11 - 4.72)</td>
<td>2.08 (1.00 - 4.31)</td>
<td>1.90 (0.91 - 3.99)</td>
<td>2.06 (0.99 - 4.29)</td>
</tr>
<tr>
<td>Masked daytime hypertension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>20 / 490</td>
<td>5.2 (3.3 - 8.0)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
</tr>
<tr>
<td>Yes</td>
<td>25 / 191</td>
<td>17.0 (11.5 - 25.1)</td>
<td>2.45 (1.36 - 4.44)</td>
<td>2.45 (1.33 - 4.51)</td>
<td>2.32 (1.25 - 4.30)</td>
<td>2.57 (1.36 - 4.83)</td>
<td>2.20 (1.18 - 4.11)</td>
</tr>
<tr>
<td>Masked nighttime hypertension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>12 / 355</td>
<td>4.3 (2.4 - 7.5)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
</tr>
<tr>
<td>Yes</td>
<td>33 / 326</td>
<td>13.1 (9.3 - 18.5)</td>
<td>2.26 (1.16 - 4.43)</td>
<td>2.12 (1.06 - 4.21)</td>
<td>1.90 (0.95 - 3.79)</td>
<td>1.67 (0.81 - 3.42)</td>
<td>1.88 (0.94 - 3.78)</td>
</tr>
<tr>
<td>Masked 24-hour hypertension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>19 / 464</td>
<td>5.2 (3.3 - 8.1)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
</tr>
<tr>
<td>Yes</td>
<td>26 / 217</td>
<td>15.6 (10.6 - 23.0)</td>
<td>2.12 (1.16 - 3.87)</td>
<td>2.05 (1.09 - 3.85)</td>
<td>1.74 (0.92 - 3.32)</td>
<td>1.71 (0.89 - 3.28)</td>
<td>1.72 (0.90 - 3.28)</td>
</tr>
</tbody>
</table>

*Crude incidence rate per 1,000 person years (95% confidence interval).

Model 1: Adjustment for age and sex.
Model 2: Adjustment for age, sex, clinic systolic blood pressure, clinic diastolic blood pressure and antihypertensive medication use.
Model 3: Adjustment for variables in Model 2 and the 10-year cardiovascular disease risk score.
Model 4: Adjustment for variables in Model 3 and nocturnal non-dipping blood pressure status.
Model 5: Adjustment for variables in Model 3 and the sleep apnea risk status.

Any masked hypertension: the presence of daytime hypertension, nighttime hypertension, or 24-hour hypertension.

Masked daytime hypertension: mean daytime systolic or diastolic ambulatory blood pressure ≥135 or ≥85 mmHg.

Masked nighttime hypertension: mean nighttime systolic or diastolic ambulatory blood pressure ≥120 or ≥70 mmHg.

Masked 24-hour hypertension: mean 24-hour systolic or diastolic ambulatory blood pressure ≥130 or ≥80 mmHg.
### Table S3. Hazard ratio for cardiovascular disease events associated with one standard deviation higher daytime, nighttime and 24-hour systolic (Panel A) and diastolic (Panel B) ambulatory blood pressure among Jackson Heart Study participants with non-elevated clinic-measured blood pressure.

<table>
<thead>
<tr>
<th>Tertile of blood pressure</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic ambulatory blood pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daytime SBP, per 12.1 mm Hg</td>
<td>1.53 (1.18 - 2.00)</td>
<td>1.59 (1.19 - 2.11)</td>
<td>1.49 (1.12 - 1.98)</td>
<td>1.63 (1.21 - 2.19)</td>
<td>1.46 (1.10 - 1.93)</td>
</tr>
<tr>
<td>Nighttime SBP, per 12.1 mm Hg</td>
<td>1.60 (1.30 - 1.97)</td>
<td>1.68 (1.33 - 2.14)</td>
<td>1.55 (1.21 - 1.97)</td>
<td>1.47 (1.13 - 1.92)</td>
<td>1.52 (1.19 - 1.93)</td>
</tr>
<tr>
<td>24-hour SBP, per 14.2 mm Hg</td>
<td>1.69 (1.31 - 2.19)</td>
<td>1.80 (1.35 - 2.40)</td>
<td>1.65 (1.24 - 2.19)</td>
<td>1.60 (1.20 - 2.14)</td>
<td>1.61 (1.22 - 2.14)</td>
</tr>
<tr>
<td>Taking antihypertensive medication (n=407)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daytime SBP, per 12.1 mm Hg</td>
<td>1.57 (1.42 - 1.72)</td>
<td>1.64 (1.49 - 1.82)</td>
<td>1.52 (1.10 - 2.09)</td>
<td>1.68 (1.20 - 2.35)</td>
<td>1.48 (1.07 - 2.04)</td>
</tr>
<tr>
<td>Nighttime SBP, per 12.1 mm Hg</td>
<td>1.60 (1.49 - 1.72)</td>
<td>1.72 (1.59 - 1.87)</td>
<td>1.57 (1.21 - 2.05)</td>
<td>1.49 (1.11 - 1.99)</td>
<td>1.54 (1.18 - 2.00)</td>
</tr>
<tr>
<td>24-hour SBP, per 14.2 mm Hg</td>
<td>1.72 (1.57 - 1.88)</td>
<td>1.86 (1.69 - 2.06)</td>
<td>1.67 (1.21 - 2.29)</td>
<td>1.62 (1.17 - 2.23)</td>
<td>1.63 (1.18 - 2.24)</td>
</tr>
<tr>
<td>Not taking antihypertensive medication (n=331)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daytime SBP, per 12.1 mm Hg</td>
<td>1.28 (1.08 - 1.53)</td>
<td>1.09 (0.90 - 1.32)</td>
<td>1.19 (0.65 - 2.18)</td>
<td>1.36 (0.71 - 2.58)</td>
<td>1.19 (0.66 - 2.16)</td>
</tr>
<tr>
<td>Nighttime SBP, per 12.1 mm Hg</td>
<td>1.40 (1.16 - 1.70)</td>
<td>1.23 (1.00 - 1.52)</td>
<td>1.49 (0.73 - 3.06)</td>
<td>1.35 (0.63 - 2.90)</td>
<td>1.50 (0.73 - 3.09)</td>
</tr>
<tr>
<td>24-hour SBP, per 14.2 mm Hg</td>
<td>1.38 (1.15 - 1.65)</td>
<td>1.19 (0.97 - 1.46)</td>
<td>1.41 (0.70 - 2.84)</td>
<td>1.44 (0.71 - 2.93)</td>
<td>1.41 (0.71 - 2.82)</td>
</tr>
<tr>
<td><strong>Panel B</strong></td>
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<tr>
<td>Diastolic ambulatory blood pressure</td>
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<td>Overall sample</td>
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<tr>
<td>Daytime DBP, per 8.6 mm Hg</td>
<td>1.47 (1.13 - 1.93)</td>
<td>1.46 (1.10 - 1.93)</td>
<td>1.43 (1.08 - 1.88)</td>
<td>1.49 (1.13 - 1.96)</td>
<td>1.4 (1.06 - 1.84)</td>
</tr>
<tr>
<td>Nighttime DBP, per 8.1 mm Hg</td>
<td>1.52 (1.20 - 1.94)</td>
<td>1.49 (1.17 - 1.91)</td>
<td>1.40 (1.10 - 1.79)</td>
<td>1.32 (1.01 - 1.72)</td>
<td>1.39 (1.09 - 1.78)</td>
</tr>
<tr>
<td>24-hour DBP, per 9.1 mm Hg</td>
<td>1.42 (1.20 - 1.69)</td>
<td>1.48 (1.23 - 1.80)</td>
<td>1.40 (1.16 - 1.69)</td>
<td>1.37 (1.13 - 1.66)</td>
<td>1.38 (1.14 - 1.67)</td>
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<tr>
<td>Taking antihypertensive medication (n=407)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daytime DBP, per 8.6 mm Hg</td>
<td>1.48 (1.34 - 1.64)</td>
<td>1.51 (1.37 - 1.68)</td>
<td>1.48 (1.08 - 2.04)</td>
<td>1.53 (1.12 - 2.09)</td>
<td>1.45 (1.06 - 1.99)</td>
</tr>
<tr>
<td>Nighttime DBP, per 8.1 mm Hg</td>
<td>1.44 (1.32 - 1.57)</td>
<td>1.47 (1.34 - 1.60)</td>
<td>1.36 (1.03 - 1.80)</td>
<td>1.26 (0.93 - 1.71)</td>
<td>1.35 (1.02 - 1.79)</td>
</tr>
<tr>
<td>24-hour DBP, per 9.1 mm Hg</td>
<td>1.44 (1.35 - 1.53)</td>
<td>1.52 (1.42 - 1.62)</td>
<td>1.41 (1.14 - 1.75)</td>
<td>1.38 (1.11 - 1.71)</td>
<td>1.39 (1.12 - 1.72)</td>
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<tr>
<td>Not taking antihypertensive medication (n=331)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Daytime DBP, per 8.6 mm Hg</td>
<td>1.44 (1.21 - 1.71)</td>
<td>1.23 (1.02 - 1.49)</td>
<td>1.34 (0.74 - 2.42)</td>
<td>1.62 (0.84 - 3.15)</td>
<td>1.33 (0.74 - 2.41)</td>
</tr>
<tr>
<td>Nighttime DBP, per 8.1 mm Hg</td>
<td>1.72 (1.45 - 2.04)</td>
<td>1.54 (1.28 - 1.84)</td>
<td>1.97 (1.04 - 3.74)</td>
<td>1.90 (0.99 - 3.84)</td>
<td>1.98 (1.04 - 3.75)</td>
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<tr>
<td>24-hour DBP, per 9.1 mm Hg</td>
<td>1.24 (1.10 - 1.40)</td>
<td>1.12 (0.98 - 1.29)</td>
<td>1.26 (0.79 - 2.01)</td>
<td>1.28 (0.79 - 2.06)</td>
<td>1.26 (0.79 - 2.01)</td>
</tr>
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</table>

SBP: systolic blood pressure.
DBP: diastolic blood pressure.
Model 1: Adjustment for age and sex.
Model 2: Adjustment for age, sex, clinic systolic blood pressure, clinic diastolic blood pressure and antihypertensive medication use.
Model 3: Adjustment for variables in Model 2 and the 10-year cardiovascular disease risk score.
Model 4: Adjustment for variables in Model 3 and nocturnal non-dipping blood pressure status.
Model 5: Adjustment for variables in Model 3 and the sleep apnea risk status.
Table S4. Mortality rates and hazard ratios for all-cause mortality associated with any masked hypertension and masked daytime, nighttime and 24-hour hypertension among Jackson Heart Study participants with non-elevated clinic-measured blood pressure overall (Panel A) and by antihypertensive medication use (Panels B and C).

<table>
<thead>
<tr>
<th>Masked hypertension status</th>
<th>Events / n at risk</th>
<th>Incidence rate (95% CI)*</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
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<tbody>
<tr>
<td>Panel A Any masked hypertension</td>
<td></td>
<td>Overall population</td>
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<tr>
<td>No</td>
<td>15 / 353</td>
<td>5.3 (3.2 - 8.8)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>29 / 385</td>
<td>9.3 (6.5 - 13.5)</td>
<td>1.16 (0.62 - 2.19)</td>
<td>1.19 (0.63 - 2.28)</td>
<td>1.15 (0.60 - 2.19)</td>
<td>1.06 (0.55 - 2.05)</td>
<td>1.14 (0.60 - 2.17)</td>
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<tr>
<td>Masked daytime hypertension</td>
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<tr>
<td>No</td>
<td>27 / 530</td>
<td>6.4 (4.4 - 9.3)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>17 / 208</td>
<td>10.1 (6.3 - 16.3)</td>
<td>1.16 (0.63 - 2.13)</td>
<td>1.18 (0.63 - 2.20)</td>
<td>1.22 (0.65 - 2.31)</td>
<td>1.28 (0.68 - 2.43)</td>
<td>1.21 (0.64 - 2.28)</td>
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<tr>
<td>Masked nighttime hypertension</td>
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<tr>
<td>No</td>
<td>16 / 382</td>
<td>5.2 (3.2 - 8.5)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<td>Yes</td>
<td>28 / 356</td>
<td>9.8 (6.8 - 14.2)</td>
<td>1.21 (0.65 - 2.26)</td>
<td>1.24 (0.65 - 2.35)</td>
<td>1.22 (0.64 - 2.32)</td>
<td>1.08 (0.56 - 2.12)</td>
<td>1.21 (0.64 - 2.31)</td>
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<tr>
<td>Masked 24-hour hypertension</td>
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<tr>
<td>No</td>
<td>22 / 504</td>
<td>5.4 (3.6 - 8.2)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>22 / 234</td>
<td>11.7 (7.7 - 17.8)</td>
<td>1.42 (0.78 - 2.57)</td>
<td>1.47 (0.79 - 2.73)</td>
<td>1.40 (0.76 - 2.59)</td>
<td>1.36 (0.73 - 2.52)</td>
<td>1.39 (0.75 - 2.59)</td>
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<tr>
<td>Panel B Taking antihypertensive medication (n=407)</td>
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<td>Any masked hypertension</td>
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<tr>
<td>No</td>
<td>10 / 168</td>
<td>7.3 (3.9 - 13.6)</td>
<td>0.88 (0.40 - 1.95)</td>
<td>0.92 (0.41 - 2.05)</td>
<td>0.82 (0.36 - 1.85)</td>
<td>0.78 (0.34 - 1.78)</td>
<td>0.82 (0.36 - 1.86)</td>
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<tr>
<td>Yes</td>
<td>18 / 239</td>
<td>9.2 (5.8 - 14.6)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<tr>
<td>Masked daytime hypertension</td>
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<td>No</td>
<td>18 / 272</td>
<td>8.2 (5.1 - 13.0)</td>
<td>0.93 (0.42 - 2.03)</td>
<td>0.95 (0.43 - 2.11)</td>
<td>1.02 (0.45 - 2.30)</td>
<td>1.06 (0.46 - 2.40)</td>
<td>1.03 (0.45 - 2.35)</td>
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<td>Yes</td>
<td>10 / 135</td>
<td>9.0 (4.8 - 16.7)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<tr>
<td>Masked nighttime hypertension</td>
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<td>No</td>
<td>10 / 189</td>
<td>6.5 (3.5 - 12.1)</td>
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<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>18 / 218</td>
<td>10.1 (6.4 - 16.0)</td>
<td>1.05 (0.47 - 2.33)</td>
<td>1.11 (0.49 - 2.49)</td>
<td>0.92 (0.40 - 2.11)</td>
<td>0.85 (0.37 - 2.00)</td>
<td>0.92 (0.40 - 2.12)</td>
</tr>
<tr>
<td>Masked 24-hour hypertension</td>
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<tr>
<td>No</td>
<td>14 / 261</td>
<td>6.6 (3.9 - 11.1)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>14 / 146</td>
<td>11.7 (6.9 - 19.8)</td>
<td>1.21 (0.57 - 2.56)</td>
<td>1.27 (0.59 - 2.75)</td>
<td>1.05 (0.48 - 2.33)</td>
<td>1.04 (0.47 - 2.30)</td>
<td>1.04 (0.47 - 2.31)</td>
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<tr>
<td>Panel C Not taking antihypertensive medication (n=331)</td>
<td></td>
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<tr>
<td>Any masked hypertension</td>
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<tr>
<td>No</td>
<td>5 / 185</td>
<td>3.4 (1.4 - 8.2)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<tr>
<td>Yes</td>
<td>11 / 146</td>
<td>9.6 (5.3 - 17.3)</td>
<td>1.96 (0.68 - 5.66)</td>
<td>1.81 (0.61 - 5.36)</td>
<td>2.05 (0.69 - 6.07)</td>
<td>1.84 (0.61 - 5.58)</td>
<td>2.13 (0.71 - 6.35)</td>
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<tr>
<td>Masked daytime hypertension</td>
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<td>No</td>
<td>9 / 258</td>
<td>4.4 (2.3 - 8.5)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
<td>1 (ref)</td>
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<td>Masked nighttime hypertension</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>
| Yes | 7 / 73  | 12.5 (5.9 - 26.1) | 1.71 (0.63 - 4.65) | 1.53 (0.53 - 4.41) | 1.63 (0.57 - 4.63) | 1.67 (0.59 - 4.73) | 1.67 (0.58 - 4.80)  
| No  | 6 / 193 | 3.9 (1.8 - 8.8)  | 1 (ref)           | 1 (ref)           | 1 (ref)           | 1 (ref)           | 1 (ref)           
| Yes | 10 / 138| 9.2 (5.0 - 17.2) | 1.62 (0.59 - 4.46) | 1.48 (0.53 - 4.18) | 1.93 (0.65 - 5.73) | 1.70 (0.56 - 5.22) | 2.07 (0.68 - 6.26)  
| Masked 24-hour hypertension |  
| No  | 8 / 243 | 4.2 (2.1 - 8.3)  | 1 (ref)           | 1 (ref)           | 1 (ref)           | 1 (ref)           | 1 (ref)           
| Yes | 8 / 88  | 11.8 (5.9 - 23.5) | 1.92 (0.72 - 5.14) | 1.74 (0.61 - 4.94) | 2.14 (0.74 - 6.20) | 2.20 (0.75 - 6.42) | 2.35 (0.79 - 7.03)  

Any masked hypertension: the presence of daytime hypertension, nighttime hypertension, or 24-hour hypertension.
Masked daytime hypertension: mean daytime systolic or diastolic ambulatory blood pressure ≥135 or ≥85 mmHg.
Masked nighttime hypertension: mean nighttime systolic or diastolic ambulatory blood pressure ≥120 or ≥70 mmHg.
Masked 24-hour hypertension: mean 24-hour systolic or diastolic ambulatory blood pressure ≥130 or ≥80 mmHg.
SBP: systolic blood pressure.
DBP: diastolic blood pressure.
*Crude incidence rate per 1000 person years (95% confidence interval).
Model 1: Adjustment for age and sex.
Model 2: Adjustment for age, sex, clinic systolic blood pressure, clinic diastolic blood pressure and antihypertensive medication use.
Model 3: Adjustment for variables in Model 2 and the 10-year mortality risk score.
Model 4: Adjustment for variables in Model 3 and nocturnal non-dipping blood pressure status.
Model 5: Adjustment for variables in Model 3 and the sleep apnea risk status.