HHS Public Access

Author manuscript

J Hum Hypertens. Author manuscript; available in PMC 2017 March 06.

Published in final edited form as:

J Hum Hypertens. 2016 December ; 30(12): 731–736. doi:10.1038/jhh.2016.27.

Ambulatory Blood Pressure Monitoring Phenotypes among Individuals With and Without Diabetes Taking Antihypertensive Medication: The Jackson Heart Study

Samantha G. Bromfield[1], **Daichi Shimbo**[2], **Alain G. Bertoni**[3], **Mario Sims**[4], **April P. Carson**[1], and **Paul Muntner**[1]

[1]Department of Epidemiology, University of Alabama at Birmingham, Birmingham, AL

[2]Department of Medicine, Columbia University Medical Center, New York, NY

[3]Department of Epidemiology and Prevention, Wake Forest School of Medicine, Winston-Salem, NC

[4]Department of Medicine, University of Mississippi Medical Center, Jackson, MS

Abstract

Ambulatory blood pressure monitoring (ABPM) can detect phenotypes associated with increased cardiovascular disease (CVD) risk. Diabetes is associated with increased CVD risk but few data are available documenting whether blood pressure (BP) phenotypes, detected by ABPM, differ between individuals with versus without diabetes. We conducted a cross-sectional analysis of 567 participants in the Jackson Heart Study, a population-based study of African Americans, taking antihypertensive medication to evaluate the association between diabetes and ABPM phenotypes. Two clinic BP measurements were taken at baseline following a standardized protocol. ABPM was performed for 24 hours following the clinic visit. ABPM phenotypes included daytime, sustained, nocturnal, and isolated nocturnal hypertension, a non-dipping BP pattern, and white coat, masked, and masked isolated nocturnal hypertension. Diabetes was defined as fasting glucose ≥126 mg/dL, hemoglobin A1c ≥6.5% (48 mmol/mol), or use of insulin or oral hypoglycemic medications. Of the included participants (mean age 62.3 years, 71.8% female), 196 (34.6%) had diabetes. After multivariable adjustment, participants with diabetes were more likely to have daytime hypertension (prevalence ratio [PR]: 1.32; 95% CI: 1.09–1.60), masked hypertension (PR: 1.46;

Address for corresponding author: Paul Muntner, PhD, Department of Epidemiology, University of Alabama at Birmingham, 1665 University Blvd, Suite 230J, Birmingham, AL 35294, pmuntner@uab.edu.

Conflicts of Interest

No potential conflicts of interest relevant to this article were reported.

Author Contributions

S.G.B. contributed to the concept and design, data analysis and interpretation, statistical analysis, drafting of the manuscript, and critical revision of the manuscript for important intellectual content. D.S. contributed to the study concept and design, data interpretation, and critical revision of the manuscript for important intellectual content. A.G.B., M.S. and A.P.C. contributed to the data interpretation and critical revision of the manuscript for important intellectual content. P.M. contributed to the study supervision, concept and design, data analysis and interpretation, statistical analysis, drafting of the manuscript, and critical revision of the manuscript for important intellectual content. S.G.B. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors read and approved the final manuscript.

Supplementary information is available at Journal of Human Hypertension's website.

95% CI: 1.11–1.93), and masked isolated nocturnal hypertension (PR: 1.39; 95% CI: 1.02–1.89). Although nocturnal hypertension was more common among participants with versus without diabetes, this association was not present after adjustment for daytime systolic BP. Diabetes was not associated with the other ABPM phenotypes investigated. This study highlights the high prevalence of ABPM phenotypes among individuals with diabetes taking antihypertensive medication.

Elevated blood pressure (BP) measured in the clinic setting is a well-established risk factor for cardiovascular disease (CVD) and end-stage renal disease among the general population as well as individuals with diabetes.[1–4] Compared with measurements taken in the clinic setting, ambulatory blood pressure monitoring (ABPM) may provide a better estimate of an individual's average BP.[5,6] Also, a mismatch can exist between hypertension defined using clinic-measured BP and BP measured outside of the clinic setting. For example, some individuals with elevated clinic BP may have non-elevated BP when measured outside of the clinic setting by ABPM (i.e., white coat hypertension).[5–8] The opposite also occurs; some individuals with non-elevated clinic BP may have elevated BP when measured outside of the clinic setting (i.e., masked hypertension).[5–8] ABPM can also identify diurnal BP patterns, including BP that does not decline normally at night (non-dipping BP) and elevated BP at night (nocturnal hypertension).[5,6] Several of these phenotypes, including elevated mean 24-hour BP, elevated nighttime BP, and non-dipping BP pattern have been associated with increased CVD risk.[5,9,10]

A recent study reported that individuals with versus without diabetes were more likely to have a higher daytime, and nighttime systolic BP (SBP) assessed by ABPM.[11] However, this study only included individuals with a clinical indication for ABPM, the results were not adjusted for potential confounders, it was conducted in a population of both treated and untreated individuals analyzed together, and did not include African Americans. A high prevalence of abnormal BP phenotypes identified using ABPM among individuals with diabetes may indicate a role for ABPM to guide treatment of hypertension in this population. The objective of this study was to compare the prevalence of ABPM phenotypes among individuals with and without diabetes in a population-based cohort of African American adults taking antihypertensive medication. Phenotypes evaluated included out-of-office BP (daytime hypertension, sustained hypertension), diurnal BP patterns (nocturnal hypertension, isolated nocturnal hypertension, non-dipping pattern) and mismatches between clinic and out-of-clinic BP (white coat hypertension, masked hypertension, and masked isolated nocturnal hypertension).

RESEARCH DESIGN AND METHODS

Study Population

The Jackson Heart Study (JHS) is a population-based study designed to examine CVD risk factors in African-American men and women. Participants were recruited from urban and rural areas of 3 counties (Hinds, Madison, and Rankin) that comprise the Jackson, Mississippi metropolitan area. Details of the design and conduct of the JHS have been published previously.[12,13] The study enrolled 5,301 African Americans between 2000 and

2004. Participants were invited to complete a 24-hour ABPM session at baseline, which 1,146 volunteers completed. For the current analysis, we excluded participants with an incomplete ABPM reading (n=100), missing clinic SBP (n=5), missing diabetes status (n=9), and missing (n=58) or not taking antihypertensive medication (n=407) for a final sample size of 567 participants. We restricted the analyses to participants taking antihypertensive medication as there were too few participants with diabetes not taking antihypertensive medication (n=51) to perform analyses in this group. The protocol for the JHS was approved by the institutional review boards at the participating institutions, including Jackson State University, Tougaloo College, and University of Mississippi Medical Center, and all participants provided written informed consent. The analyses of the data that we report were approved by the institutional review board at the University of Alabama at Birmingham.

Data Collection

Data for the current analyses were collected by questionnaire, a clinic examination and ABPM. Data collected through the interview-administered questionnaire included age, sex, education, marital status, current smoking, physical activity, history of stroke and myocardial infarction, and self-reported use of antihypertensive medication. Using a modified Baecke questionnaire, duration, frequency and intensity of physical activity were reported in four domains (active living, work, home life and sports and exercise).[14,15] Participants were considered to be taking antihypertensive medication if they self-reported use of medication to lower BP in the 2 weeks prior to their clinic visit. The names of all classes of antihypertensive medication being taken in the 2 weeks prior to the clinic visit were recorded at baseline during a pill bottle review. During the clinic examination, trained technicians measured height, weight, and BP. Measured height and weight were used to calculate body mass index (BMI).

Participants were asked to fast overnight prior to their JHS examination. Venipuncture was done after participants were in a supine position for 20 minutes. Blood was collected within a designated one-hour time window following a standardized protocol. Total and HDL-cholesterol, serum glucose, and hemoglobin A1c (HbA1c) were measured from blood samples taken during the clinic examination. Total and HDL-cholesterol were measured using a Roche COBAS Fara analyzer in the central laboratory, located at the University of Minnesota Department of Laboratory Medicine and Pathology. Fasting serum glucose was measured using a glucose oxidase method on a Vitros 950 or 250 analyzer at the University of Mississippi Medical Center. HbA1c was measured using a TOSOH high performance liquid chromatography system in the central laboratory at the University of Minnesota. Diabetes was defined as fasting plasma glucose ≥ 126 mg/dL, HbA1c ≥ 6.5% (48 mmol/mol), or use of insulin or other glucose lowering medications within 2 weeks prior to the clinic visit.

Clinic BP Measurements—Clinic BP was measured at baseline following a standardized protocol using a Hawksley random zero sphygmomanometer (RZS) and Littman stethoscope. The appropriate cuff size was determined by measuring each participant's arm circumference. Two BP readings were obtained after 5 minutes of seated rest with a one-

minute rest between measurements. The mean of these measurements was used to define clinic SBP and diastolic BP (DBP).

Ambulatory BP Measurements—ABPM was performed following the clinic examination using a SpaceLabs 90207 device. This device uses oscillometry to measure BP and automatically adjusts the level of the cuff inflation based on the participant's SBP. Cuff sizes were selected after measuring participants' non-dominant arm circumference. Measurements were taken every 20 minutes during the 24-hour monitoring period. After 24 hours of monitoring, participants returned to the JHS Examination Center to have the device removed. Consistent with the International Database of Ambulatory Blood Pressure and Cardiovascular Disease (IDACO), daytime was defined as 10 am to 8 pm and nighttime was defined as 12 am to 6 am.[16] For an ABPM measurement to be considered complete, a participant was required to have at least 10 daytime and 5 nighttime SBP and DBP measurements. On average, participants with complete ABPM had 23 daytime measurements and 17 nighttime measurements.

BP Phenotypes—Elevated clinic BP was defined as mean clinic SBP ≥ 140 mmHg or DBP ≥ 90 mmHg; elevated daytime BP as mean daytime SBP ≥ 135 mmHg or DBP ≥ 85 mmHg; and elevated nighttime BP as mean nighttime SBP ≥ 120 mmHg or DBP ≥ 70 mmHg [17]. Using clinic BP and ABPM, we evaluated three phenotype domains: elevated mean clinic and/or daytime BP, diurnal BP patterns, and a mismatch between clinical hypertension and out-of-clinic hypertension (Table 1). Elevated mean clinic and/or daytime BP phenotypes included clinic hypertension, daytime hypertension, and sustained hypertension. Diurnal BP patterns included nocturnal hypertension, isolated nocturnal hypertension, and a non-dipping BP pattern. Mismatches between clinical hypertension and out-of-clinic hypertension included white coat hypertension, masked hypertension, and masked isolated nocturnal hypertension.

BP Comparability Study—A Blood Pressure Comparability Study was conducted after the transition from the use of a Hawksley RZS to an Omron automatic oscillatory device (AOD) in the second clinic visit. Two technicians took two BP measurements simultaneously using a Y connector and double-headed stethoscope with the RZS and AOD devices, separately. BP measurements obtained at baseline with the RZS were calibrated to measurements obtained with the AOD device using the following calibration equations to predict SBP and DBP:

$$\begin{aligned} \mathrm{SBP}_{\mathrm{AOD}} &= \mathrm{SBP}_{\mathrm{RZS}} + 11.0 - 0.1 * \mathrm{SBP}_{\mathrm{RZS}} \\ \mathrm{DBP}_{\mathrm{AOD}} &= \mathrm{DBP}_{\mathrm{RZS}} + 10.3 - 0.2 * \mathrm{DBP}_{\mathrm{RZS}} \end{aligned}$$

This equation modeled the difference between the AOD and RZS as a function of RZS.

Statistical Analysis

Characteristics were calculated for participants with and without diabetes, separately, and compared using t-tests and chi-square tests as appropriate. The prevalence of clinic hypertension and BP phenotypes assessed by ABPM was calculated for participants with

and without diabetes and were compared using chi-square tests. Binomial regression models were used to calculate prevalence ratios (PR) for each BP phenotype assessed by ABPM comparing participants with versus without diabetes. Models with progressive adjustment were fitted. Model 1 adjusted for age and sex. Model 2 included additional adjustment for education, marital status, current smoking, physical activity, and BMI. Model 3 included all of the variables in model 2 plus history of stroke, history of myocardial infarction, total and HDL-cholesterol, and taking ≥3 or more classes of antihypertensive medication. For the analysis of nocturnal hypertension, isolated nocturnal hypertension, and non-dipping pattern, a fourth model (model 4) included adjustment for daytime SBP. In a sensitivity analysis, we defined masked hypertension as non-elevated clinic BP with elevated daytime BP and/or elevated nighttime BP and we calculated PRs for masked hypertension associated with diabetes using this definition. We conducted an additional sensitivity analysis after calibrating the RZS BP measurements to and an AOD device. All variables with missing data were imputed with 10 data sets using chained equations.[18] The percentage of data missing for each variable included in the analysis was 0.4% for education, 0.2% for marital status, 0.7% for current smoking, 8.8% for total cholesterol, and 9.0% for HDL-cholesterol. All analyses were conducted using STATA/IC 13 (Stata Corporation, College Station, Texas).

RESULTS

Of the 567 participants included in this analysis, the mean age was 62.3 years and 71.8% were female. Overall, 196 (34.6%) participants had diabetes. BMI was higher and HDL-cholesterol was lower among participants with versus without diabetes (Table 2). Participants with diabetes were more likely than their counterparts without diabetes to be taking 3 or more classes of antihypertensive medication (31.6% versus 17.8%). Mean 24-hour, daytime, and nighttime SBP were higher and mean clinic DBP was lower among participants with compared to their counterparts without diabetes.

Elevated Mean Clinic and/or Daytime BP

The prevalence of clinic and sustained hypertension was similar among participants with compared to without diabetes (Table 3). Diabetes was associated with a higher prevalence of daytime hypertension. This association remained present after full multivariable adjustment.

Diurnal BP Patterns

The prevalence of nocturnal hypertension and isolated nocturnal hypertension were higher among participants with compared to without diabetes (Table 4). The associations for nocturnal hypertension and isolated nocturnal hypertension remained statistically significant after age and sex adjustment and further adjustment for education, marital status, current smoking, physical activity, BMI, history of stroke, history of myocardial infarction, and total and HDL-cholesterol. These associations were attenuated after adjustment for daytime SBP. The prevalence of non-dipping was similar among participants with and without diabetes.

Mismatch Between Clinical Hypertension and Out-of-Clinic Hypertension Status

The prevalence of white coat hypertension was lower for participants with compared to those without diabetes (25.5% versus 35.5%, Table 5). In contrast, the prevalence of masked hypertension and masked isolated nocturnal hypertension were higher among participants with compared to without diabetes. Diabetes was associated with a higher prevalence of masked hypertension and masked isolated nocturnal hypertension after multivariable adjustment. In a sensitivity analysis, diabetes was associated with an increased prevalence of masked hypertension when defined by non-elevated clinic BP with elevated daytime BP and/or elevated nighttime BP (Supplemental Table 1).

Calibrated BP

The prevalence and prevalence ratios for diabetes associated with clinic, sustained, white coat, masked, and masked isolated nocturnal hypertension were similar when using BP measurements from the RZS device and BP calibrated to an AOD (Supplemental Table 2).

DISCUSSION

In the current study, the prevalence of daytime hypertension, masked hypertension, and masked isolated nocturnal hypertension was higher among participants with compared to their counterparts without diabetes. In contrast, white coat hypertension, a phenotype that has not been consistently associated with increased CVD risk in most prior studies, was less prevalent among participants with diabetes.[19] Overall, these data suggest that ABPM may provide information on BP beyond that obtained from measurements taken in the clinic setting.

Previous analyses have reported differences in BP phenotypes assessed by ABPM among individuals with compared to their counterparts without diabetes, including those taking and not taking antihypertensive medication.[11,20] Gorostidi and colleagues reported higher mean daytime SBP (135.4 versus 131.8 mm Hg), nighttime SBP (126.0 versus 121.0 mm Hg), and 24-hour SBP (133.0 versus 129.0 mm Hg) among hypertensive individuals with versus without diabetes.[11] Additionally, the prevalence of a non-dipping BP was more common among hypertensive individuals with diabetes (64.2%) compared to their counterparts without diabetes (51.6%). This study was restricted to a population with a clinical indication for ABPM, did not include African Americans, and results were not presented after adjustment for potential confounders. In the current study, we found a similar prevalence of non-dipping pattern among participants with versus without diabetes. The prevalence of non-dipping BP was high in both groups which is consistent with this pattern being more common among African Americans.[21] In IDACO, masked hypertension was more common in participants with versus without diabetes (29.3% versus 18.8%), consistent with our findings.[20] However, these aforementioned studies did not include African Americans. African Americans are more likely than whites to have many BP phenotypes assessed by ABPM, including masked hypertension, nocturnal hypertension and non-dipping BP.[22,23] The current study extends findings of prior studies to a large sample of African Americans with a high prevalence of diabetes.

Studies have shown that out-of-office BP have stronger associations with CVD outcomes when compared with clinic BP among individuals with diabetes.[24,25] In a prospective study of 607 individuals with diabetes, a stronger association was present between mean asleep SBP with CVD events (hazard ratio: 1.71, 95% CI: 1.45–2.01 for each standard deviation higher mean asleep SBP) compared to mean clinic SBP (hazard ratio: 1.44, 95% CI: 1.19–1.74 for each standard deviation higher mean clinic SBP).[24] In a separate study of 565 individuals with diabetes, daytime and nighttime SBP were associated with an increased risk of CVD events (hazard ratio: 1.45, 95% CI: 1.17–1.80 for 15 mm Hg higher daytime and hazard ratio: 1.37, 95% CI: 1.12–1.67 for each 17 mm Hg higher nighttime SBP), while CVD risk was not increased at higher clinic SBP (hazard ratio: 1.16, 95% CI: 0.91–1.48, for each 17 mm Hg higher clinic SBP).[25] Given the stronger association of BP assessed by ABPM versus clinic BP with CVD morbidity, further evaluating BP phenotypes assessed by ABPM in relation to CVD outcomes among individuals with diabetes may provide important information for guiding treatment this population.

Recent guidelines by the UK National Institute for Health and Clinical Excellence (NICE) and US Preventive Services Task Force (USPSTF) suggest that the diagnosis of clinic hypertension be confirmed using ABPM in efforts to avoid misdiagnosis and overtreatment.[26,27] However, the NICE and USPSTF recommendations are focused on diagnosing hypertension in untreated individuals and they did not mention recommendations for treated populations. The European Society of Hypertension (ESH) recommends the use of ABPM in individuals with diabetes for the identification of masked hypertension.[28] In a more recent position paper, the ESH highlighted the usefulness of ABPM in identifying non-dipping patterns and nocturnal hypertension in individuals with diabetes as these phenotypes are common in this population.[6] In the current study the prevalence of masked and nocturnal hypertension were high, which supports the ESH recommendations for ABPM in individuals with diabetes.

The current study has several strengths, including the collection of ABPM and clinic BP following standardized protocols. Few population-based studies have conducted ABPM in African Americans and those that did had small sample sizes. This study included a large population-based sample of African Americans with ABPM data. A large number of covariates were collected as part of the JHS, allowing us to adjust for multiple potential confounders. Despite these strengths, the findings from this study should be interpreted in the context of known and potential limitations. Data were collected between 2000–2004 and the increased prevalence of diabetes in U.S. adults from 7.4% in 1999–2000 to 11.9% in 2007–2008 may affect these results.[29] Clinic BP was measured using a Hawksley Random Zero device. ABPM was only performed in a sub-sample of JHS participants. Clinic BP was measured at a single visit and ABPM was only performed a single time. Therefore, some participants' hypertension status may have been misclassified. There were too few participants not taking antihypertensive medication with diabetes to study the association of diabetes with ABPM phenotypes in untreated individuals. However, more than 50% of US adults with diabetes take antihypertensive medication making this a valuable population to study.[29]

In conclusion, in the current population-based study of African Americans taking antihypertensive medication, daytime, masked and masked isolated nocturnal hypertension were more prevalent among participants with compared to those without diabetes. Nocturnal hypertension was more common among participants with diabetes but this association was no longer present after adjustment for daytime SBP. This study highlights the high prevalence of ABPM phenotypes among individuals with diabetes taking antihypertensive medication.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding

The Jackson Heart Study is supported by contracts HHSN268201300046C, HHSN268201300047C, HHSN268201300048C, HHSN268201300049C, HHSN268201300050C from the National Heart, Lung, and Blood Institute (NHLBI) and the National Institute on Minority Health and Health Disparities (NIMHD).

References

1. He J, Whelton PK. Elevated systolic blood pressure as a risk factor for cardiovascular and renal disease. J Hypertens Suppl. 1999; 17:S7–13. [PubMed: 10465061]
2. Klag MJ, Whelton PK, Randall BL, Neaton JD, Brancati FL, Ford CE, et al. Blood Pressure and End-Stage Renal Disease in Men. N Engl J Med. 1996; 334:13–18. [PubMed: 7494564]
3. Hypertension in Diabetes Study Group. Hypertension in Diabetes Study (HDS): I. Prevalence of hypertension in newly presenting type 2 diabetic patients and the association with risk factors for cardiovascular and diabetic complications. J Hypertens. 1993; 11:309–17. [PubMed: 8387089]
4. Foley RN, Parfrey PS, Harnett JD, Kent GM, Murray DC, Barre PE. Impact of hypertension on cardiomyopathy, morbidity and mortality in end-stage renal disease. Kidney Int. 1996; 49:1379–85. [PubMed: 8731103]
5. Pickering TG, Shimbo D, Haas D. Ambulatory blood-pressure monitoring. N Engl J Med. 2006; 354:2368–74. [PubMed: 16738273]
6. O'Brien E, Parati G, Stergiou G, Asmar R, Beilin L, Bilo G, et al. European society of hypertension position paper on ambulatory blood pressure monitoring. J Hypertens. 2013; 31:1731–68. [PubMed: 24029863]
7. Turner JR, Viera AJ, Shimbo D. Ambulatory Blood Pressure Monitoring in Clinical Practice: A Review. Am J Med. 2014; doi: 10.1016/j.amjmed.2014.07.021
8. Mancia G, Bombelli M, Seravalle G, Grassi G. Diagnosis and management of patients with white-coat and masked hypertension. Nat Rev Cardiol. 2011; 8:686–93. [PubMed: 21826071]
9. Ohkubo T, Hozawa A, Yamaguchi J, Kikuya M, Ohmori K, Michimata M, et al. Prognostic significance of the nocturnal decline in blood pressure in individuals with and without high 24-h blood pressure: the Ohasama study. J Hypertens. 2002; 20:2183–9. [PubMed: 12409956]
10. Kario K, Pickering TG, Umeda Y, Hoshide S, Hoshide Y, Morinari M, et al. Morning surge in blood pressure as a predictor of silent and clinical cerebrovascular disease in elderly hypertensives: a prospective study. Circulation. 2003; 107:1401–6. [PubMed: 12642361]
11. Gorostidi M, de la Sierra A, González-Albarrán O, Segura J, de la Cruz JJ, Vinyoles E, et al. Abnormalities in ambulatory blood pressure monitoring in hypertensive patients with diabetes. Hypertens Res. 2011; 34:1185–9. [PubMed: 21833002]
12. Taylor HA, Wilson JG, Jones DW, Sarpong DF, Srinivasan A, Garrison RJ, et al. Toward resolution of cardiovascular health disparities in African Americans: design and methods of the Jackson Heart Study. Ethn Dis. 2005; 15:S6–4–17.

13. Carpenter MA, Crow R, Steffes M, Rock W, Heilbraun J, Evans G, et al. Laboratory, reading center, and coordinating center data management methods in the Jackson Heart Study. Am J Med Sci. 2004; 328:131–44. [PubMed: 15367870]
14. Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. Am J Clin Nutr. 1982; 36:936–42. [PubMed: 7137077]
15. Dubbert PM, Carithers T, Ainsworth BE, Taylor HA, Wilson G, Wyatt SB. Physical activity assessment methods in the Jackson Heart Study. Ethn Dis. 2005; 15:S6–56–61.
16. Thijs L, Hansen TW, Kikuya M, Björklund-Bodegård K, Li Y, Dolan E, et al. The International Database of Ambulatory Blood Pressure in relation to Cardiovascular Outcome (IDACO): protocol and research perspectives. Blood Press Monit. 2007; 12:255–62. [PubMed: 17760218]
17. Mancia G, Fagard R, Narkiewicz K, Redon J, Zanchetti A, Bohm M, et al. 2013 ESH/ESC Guidelines for the management of arterial hypertension: The Task Force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). J Hypertens. 2013; 31:1925–1938. [PubMed: 24107724]
18. White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and guidance for practice. Stat Med. 2011; 30:377–99. [PubMed: 21225900]
19. Verdecchia P, Porcellati C, Schillaci G, Borgioni C, Ciucci A, Battistelli M, et al. Ambulatory blood pressure. An independent predictor of prognosis in essential hypertension. Hypertension. 1994; 24:793–801. [PubMed: 7995639]
20. Franklin SS, Thijs L, Li Y, Hansen TW, Boggia J, Liu Y, et al. Masked hypertension in diabetes mellitus: treatment implications for clinical practice. Hypertension. 2013; 61:964–71. [PubMed: 23478096]
21. Profant J, Dimsdale JE. Race and diurnal blood pressure patterns. A review and meta-analysis. Hypertension. 1999; 33:1099–104. [PubMed: 10334794]
22. Viera AJ, Zhu S, Hinderliter AL, Shimbo D, Person SD, Jacobs DR. Diurnal blood pressure pattern and development of prehypertension or hypertension in young adults: the CARDIA study. J Am Soc Hypertens. 2010; 5:48–55.
23. Muntner P, Lewis CE, Diaz KM, Carson AP, Kim Y, Calhoun D, et al. Racial Differences in Abnormal Ambulatory Blood Pressure Monitoring Measures: Results From the Coronary Artery Risk Development in Young Adults (CARDIA) Study. Am J Hypertens. 2014; doi: 10.1093/ajh/hpu193
24. Hermida RC, Ayala DE, Mojón A, Fernández JR. Sleep-time blood pressure as a therapeutic target for cardiovascular risk reduction in type 2 diabetes. Am J Hypertens. 2012; 25:325–34. [PubMed: 22158066]
25. Salles GF, Leite NC, Pereira BB, Nascimento EM, Cardoso CRL. Prognostic impact of clinic and ambulatory blood pressure components in high-risk type 2 diabetic patients: the Rio de Janeiro Type 2 Diabetes Cohort Study. J Hypertens. 2013; 31:2176–86. [PubMed: 24029864]
26. National Institute for Health and Clinical Excellence. The clinical managament of primary hypertension in adults: clinical guideline. 2011. p. 127
27. Siu AL. Screening for High Blood Pressure in Adults: U.S. Preventive Services Task Force Recommendation Statement. Ann Intern Med. 2015; 163:778–86. [PubMed: 26458123]
28. O'Brien E, Asmar R, Beilin L, Imai Y, Mallion J-M, Mancia G, et al. European Society of Hypertension recommendations for conventional, ambulatory and home blood pressure measurement. J Hypertens. 2003; 21:821–48. [PubMed: 12714851]
29. Kuznik A, Mardekian J. Trends in utilization of lipid- and blood pressure-lowering agents and goal attainment among the U.S. diabetic population, 1999–2008. Cardiovasc Diabetol. 2011; 10:31. [PubMed: 21496321]

Summary Table

What is known about the topic
• Elevated blood pressure is a known risk factor for cardiovascular disease.
• Compared to clinic blood pressure measurements, ambulatory blood pressure provides a better estimate of mean blood pressure.
• In a previous study, adults with versus without diabetes were more likely to have higher daytime and nighttime systolic blood pressure.
What this study adds
• Among African Americans taking antihypertensive medication, there is a higher prevalence of daytime, masked, and masked isolated nocturnal hypertension in those with compared to without diabetes.
• Ambulatory blood pressure monitoring may be useful for identifying adults with diabetes who have increased risk for cardiovascular disease-related BP phenotypes.

Table 1

Definitions of clinic hypertension and ambulatory blood pressure monitoring phenotypes.

Phenotype	Clinic Measurements	ABPM Measurements
Elevated mean clinic blood pressure and/or daytime blood pressure		
Clinic Hypertension	Mean SBP ≥ 140 mmHg or DBP ≥ 90 mmHg	-
Daytime Hypertension	-	Mean daytime SBP ≥ 135 mmHg or DBP ≥ 85 mmHg
Sustained Hypertension †	Mean SBP ≥ 140 mmHg or DBP ≥ 90 mmHg	Mean daytime SBP ≥ 135 mmHg or DBP ≥ 85 mmHg
Diurnal blood pressure patterns		
Nocturnal Hypertension	-	Mean nighttime SBP ≥ 120 mmHg or DBP ≥ 70 mmHg
Isolated Nocturnal Hypertension	-	Mean daytime SBP < 135 mmHg and DBP < 85 mmHg and mean nighttime SBP ≥ 120 mmHg or DBP ≥ 70 mmHg
Non-Dipping Pattern	-	Nocturnal decline in SBP ≤ 10% from daytime SBP
Mismatch between clinic and out-of-clinic hypertension		
White Coat Hypertension ††	Mean SBP ≥140 mmHg or DBP ≥ 90 mmHg	Mean daytime SBP < 135 mmHg and DBP < 85 mmHg
Masked Hypertension †††	Mean SBP < 140 mmHg and DBP < 90 mmHg	Mean daytime SBP ≥ 135 mmHg or DBP ≥ 85 mmHg.
Masked Isolated Nocturnal Hypertension †††	Mean SBP < 140 mmHg and DBP < 90 mmHg	Mean daytime SBP < 135 mmHg and DBP < 85 mmHg and mean nighttime SBP ≥ 120 mmHg or DBP ≥ 70 mmHg

SBP - systolic blood pressure; DBP – diastolic blood pressure; ABPM – ambulatory blood pressure monitoring

† Analyses of sustained hypertension included the full population.

†† Analyses of white coat hypertension were restricted to participants with clinic hypertension.

††† Analyses of masked hypertension and masked isolated nocturnal hypertension were restricted to participants without clinic hypertension.

Table 2

Characteristics of Jackson Heart Study participants taking antihypertensive medication by diabetes status.

	No Diabetes (n = 371)	Diabetes (n = 196)	p-value
Age, years	62.1 (9.7)	62.8 (8.8)	0.423
Men	27.2%	30.1%	0.469
Married	52.3%	55.1%	0.524
Less than high school education	21.0%	24.5%	0.345
Current smoker	8.7%	8.7%	0.985
No physical activity	47.4%	53.1%	0.203
BMI, kg/m^2	31.2 (6.2)	33.4 (6.4)	<0.001
Total cholesterol, mg/dL	200.2 (35.8)	198.9 (46.1)	0.743
HDL-cholesterol, mg/dL	55.9 (16.1)	49.5 (11.9)	<0.001
History of stroke	4.6%	7.7%	0.132
History of MI	5.9%	5.6%	0.878
Taking ≥3 Classes of Antihypertensive Medications	17.8%	31.6%	0.004
Clinic Blood Pressure			
SBP, mm Hg	129.3 (16.2)	130.4 (18.4)	0.471
DBP, mm Hg	78.1 (10.2)	75.1 (10.3)	0.001
24-Hour Blood Pressure			
SBP, mm Hg	126.4 (13.0)	132.8 (14.7)	<0.001
DBP, mm Hg	74.4 (8.8)	73.6 (9.7)	0.318
Daytime Blood Pressure			
SBP, mm Hg	129.3 (12.9)	134.8 (14.4)	<0.001
DBP, mm Hg	78.0 (9.0)	76.7 (10.3)	0.143
Nighttime Blood Pressure			
SBP, mm Hg	121.2 (15.1)	129.0 (17.2)	<0.001
DBP, mm Hg	68.8 (10.1)	68.8 (10.2)	0.962

Numbers reported are mean (standard deviation) unless otherwise indicated.

BMI: body mass index; HDL: high density lipoprotein; MI: myocardial infarction; SBP: systolic blood pressure, DBP: diastolic blood pressure.

Table 3

Prevalence ratios for clinic hypertension, daytime hypertension, and sustained hypertension associated with diabetes among Jackson Heart Study participants taking antihypertensive medication.

	No Diabetes	Diabetes
Clinic Hypertension	N=371	N=196
Prevalence, n (%)	110 (29.7%)	55 (28.1%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	0.94 (0.72–1.23)
Model 2	1 (ref)	0.93 (0.71–1.23)
Model 3	1 (ref)	0.92 (0.70–1.22)
Daytime Hypertension	N=371	N=196
Prevalence, n (%)	148 (39.9%)	96 (49.0%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	1.21 (1.00–1.46)
Model 2	1 (ref)	1.26 (1.05–1.53)
Model 3	1 (ref)	1.32 (1.09–1.60)
Sustained Hypertension	N=110	N=55
Prevalence, n (%)	71 (64.6%)	41 (74.6%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	1.08 (0.77–1.51)
Model 2	1 (ref)	1.07 (0.76–1.51)
Model 3	1 (ref)	1.12 (0.78–1.60)

CI: confidence interval

See Table 1 for the definitions of clinic hypertension, daytime hypertension and sustained hypertension.

Model 1 is adjusted for age and sex.

Model 2 is adjusted for variables in Model 1 + education, marital status, current smoking, physical activity, BMI.

Model 3 is adjusted for variables in Model 2 + history of stroke, history of myocardial infarction, total and HDL-cholesterol, and taking ≥ 3 classes of antihypertensive medications.

Table 4

Prevalence ratios for nocturnal hypertension, isolated nocturnal hypertension, and non-dipping pattern associated with diabetes among Jackson Heart Study participants taking antihypertensive medication.

	No Diabetes	Diabetes
Nocturnal Hypertension	N=371	N=196
Prevalence, n (%)	207 (55.8%)	143 (73.0%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	1.29 (1.14–1.46)
Model 2	1 (ref)	1.29 (1.14–1.46)
Model 3	1 (ref)	1.28 (1.12–1.45)
Model 4	1 (ref)	1.07 (0.95–1.21)
Isolated Nocturnal Hypertension	N=223	N=100
Prevalence, n (%)	81 (36.3%)	52 (52.0%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	1.41 (1.10–1.82)
Model 2	1 (ref)	1.36 (1.05–1.78)
Model 3	1 (ref)	1.27 (0.97–1.66)
Model 4	1 (ref)	1.08 (0.83–1.40)
Non-dipping Pattern	N=371	N=196
Prevalence, n (%)	252 (67.9%)	143 (73.0%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	1.07 (0.96–1.19)
Model 2	1 (ref)	1.03 (0.93–1.15)
Model 3	1 (ref)	1.03 (0.92–1.15)
Model 4	1 (ref)	1.07 (0.95–1.20)

CI: confidence interval

See Table 1 for the definitions of nocturnal hypertension, isolated nocturnal hypertension and non-dipping pattern.

Analyses of isolated nocturnal hypertension restricted to participants without elevated daytime hypertension.

Model 1 is adjusted for age and sex.

Model 2 is adjusted for variables in Model 1 + education, marital status, current smoking, physical activity, BMI.

Model 3 is adjusted for variables in Model 2 + history of stroke, history of myocardial infarction, total and HDL-cholesterol, and taking ≥ 3 classes of antihypertensive medications.

Model 4 is adjusted for variables in Model 3 + daytime SBP.

Table 5

Prevalence ratios for white coat hypertension, masked hypertension, and masked isolated nocturnal hypertension associated with diabetes among Jackson Heart Study participants taking antihypertensive medication.

	No Diabetes	Diabetes
White Coat Hypertension	N=110	N=55
Prevalence, n (%)	39 (35.5%)	14 (25.5%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	0.78 (0.47–1.31)
Model 2	1 (ref)	0.79 (0.47–1.32)
Model 3	1 (ref)	0.66 (0.39–1.11)
Masked Hypertension	N=261	N=141
Prevalence, n (%)	77 (29.5%)	55 (39.0%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	1.32 (1.00–1.74)
Model 2	1 (ref)	1.43 (1.08–1.88)
Model 3	1 (ref)	1.46 (1.11–1.93)
Masked Isolated Nocturnal Hypertension	N=184	N=86
Prevalence, n (%)	61 (33.2%)	42 (48.8%)
Prevalence ratio (95% CI)		
Model 1	1 (ref)	1.49 (1.11–2.00)
Model 2	1 (ref)	1.48 (1.09–2.01)
Model 3	1 (ref)	1.38 (1.02–1.89)

CI: confidence interval

See Table 1 for the definitions of white coat hypertension, masked hypertension and masked isolated nocturnal hypertension.

Analyses of white coat hypertension restricted to participants with elevated clinic blood pressure.

Analyses of masked hypertension restricted to participants without elevated clinic blood pressure.

Analyses of masked isolated nocturnal hypertension restricted to participants without elevated clinic blood pressure and without daytime hypertension.

Model 1 is adjusted for age and sex.

Model 2 is adjusted for variables in Model 1 + education, marital status, current smoking, physical activity, BMI.

Model 3 is adjusted for variables in Model 2 + history of stroke, history of myocardial infarction, total and HDL-cholesterol, and taking ≥ 3 classes of antihypertensive medications.