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Understanding Disparities In Hypertension Treatment Cascade And Validating Blood Pressure Measurement Among Persons Living With Or At Risk For Hiv

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UNDERSTANDING DISPARITIES IN HYPERTENSION TREATMENT CASCADE AND VALIDATING BLOOD PRESSURE MEASUREMENT AMONG PERSONS LIVING WITH OR AT RISK FOR HIV

by

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UNDERSTANDING DISPARITIES IN HYPERTENSION TREATMENT CASCADE AND VALIDATING BLOOD PRESSURE MEASUREMENT AMONG PERSONS LIVING WITH OR AT RISK FOR HIV

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EPIDEMIOLOGY

ABSTRACT

In the United States, 44% of adult women >18 years have hypertension. Although non-Hispanic Black adults were more likely to be aware of and treated for hypertension compared to non-Hispanic White adults, Black individuals had the highest prevalence of uncontrolled hypertension. Persons living with HIV have a higher prevalence of hypertension, which is a major modifiable risk factor for cardiovascular disease. Similar to the geographic distribution of hypertension in the US, people living in the South have higher incidence of both hypertension and HIV diagnoses compared to other US regions. Furthermore, accurate diagnosis of hypertension and initiation of treatment is vital among the 42% of US adults who have obesity. Overestimation of blood pressure can occur when the standard brachial cuff used on the upper arm is too small. An alternative approach in capturing blood pressure in individuals with obesity is the use of forearm radial cuffs, which is significantly higher than brachial blood pressure. The goal of this dissertation was to (1) evaluate cross-sectional associations between race and ethnicity, as well as HIV status, and prevalence, awareness, treatment, and control of hypertension among women in the South participating in the Women's Interagency HIV Study; (2) prospectively examine incidence of hypertension and hypertension awareness, treatment, and control among women in the same cohort; (3) compare and harmonize radial and brachial blood pressure among participants with mid-arm circumference >40 cm in select Multicenter

AIDS Cohort Study/Women's Interagency HIV Study-Combined Cohort Study sites. I found non-Hispanic Black women had higher prevalence of hypertension and slower time to controlled hypertension compared to non-Hispanic White and Hispanic women. Among women with hypertension, those living with HIV were more likely to use antihypertensive medication and have faster time to treatment compared to women living without HIV. Among participants with obesity, prevalent hypertension increased, and control decreased based on estimated radial blood pressure compared to measured brachial blood pressure. Due to the elevated burden of comorbidities and increased access to care among people living with HIV, the patterns of hypertension prevalence, treatment, and control may differ from prior studies, especially among those with large arm circumference.

Keywords: hypertension, HIV, racial and ethnic minorities, radial blood pressure, brachial blood pressure, obesity

DEDICATION

To my family, and friends at East Huntsville Baptist Church.

I am thankful for your continuous prayers

That shaped me to be the young professional I am today.

To God, who has been my unwavering support.

“I can do all things through Christ who strengthens me”

Philippians 4:13 *New King James Version*

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AWARENESS, TREATMENT, AND CONTROL OF HYPERTENSION AMONG WOMEN AT RISK OR LIVING WITH HIV IN THE US SOUTH: A PROSPECTIVE STUDY

INTRODUCTION

Hypertension in the United States

High blood pressure (BP), also known as hypertension, defined as systolic and diastolic blood pressure ≥130/80 mmHg, is associated with a higher risk of developing cardiovascular disease (CVD), stroke, kidney disease, cognitive impairment, and premature mortality.[1-3] Currently, 48% of US adults aged >18 years have hypertension, of whom only 23% have their hypertension under control.[4] The following modifiable risk factors for CVD are common among people living with hypertension: cigarette use, diabetes, obesity, poor diet, and low physical activity.[1] Among women, CVD mortality could decrease by 38% if hypertension was diagnosed and controlled.[5] One framework to improve hypertension management is the hypertension treatment cascade, which consists of awareness, treatment, and control of hypertension.[6] Typically, awareness and treatment of hypertension are obtained through self-report and controlled hypertension is verified as <130/80 mmHg for individuals taking antihypertensive medication.[7]

Racial and ethnic disparities in hypertension

There are persistent racial and ethnic disparities in the hypertension treatment cascade in the United States (US). The mortality rate per 100,000 attributable to hypertension in 2019 was highest for non-Hispanic (NH) Black women (38.7) compared to NH White (20.6) and Hispanic women (17.4).[8,9] The age-adjusted prevalence for hypertension was highest for NH Black women (58%) compared to NH White and

Hispanic women (41% and 41%, respectively).[5] NH Black adults were more likely to be aware of and treated for hypertension compared to NH White adults.[10] Although Black women are more likely to use antihypertensive medications compared to White women, Black women continue to have poorer control of high BP and higher prevalence of treatment resistant hypertension.[7,11]

Significance of hypertension among people living with HIV

Among people living with HIV (PLWH) in the US, the leading causes of death are non-communicable disease, including CVD, in which hypertension is a major risk factor.[12] PLWH have a higher prevalence of hypertension compared to people living without HIV (PLWOH).[13-15] Additionally, PLWH have a higher burden of multiple comorbidities and develop them earlier in life compared to PLWOH.[16,17] Because of the elevated burden of comorbidities and increased access to care among PLWH, the patterns of hypertension treatment cascade may differ from prior studies in general population samples.

People with access to healthcare are more likely to be adherent to medications for management of HIV, which might lead to improvements in the hypertension treatment cascade as well.[18,19] A multicenter cohort study among PLWH noticed improvements in hypertension awareness, treatment, and control over a median of 3.5 years for participants with high BP after enrollment in a health-based study.[20] Hypertension awareness increased from 63 to 92%, treatment increased from 55 to 79%, and control increased from 35 to 59% during the study period.[20] Thus, participation in health-focused studies may improve management of hypertension by providing linkage to clinical care.

Women with annual healthcare visits are more likely to be aware of their hypertension diagnosis and be treated accordingly.[10]

Geographical and gender differences in hypertension and HIV

Black individuals living in the US have the highest prevalence of hypertension in the world.[8] Data from the National Health and Nutrition Examination Survey from 2003-2014 showed NH Black individuals born outside of the US had 39% lower odds of having hypertension compared to US-born NH Black individuals.[8] The US Southeast, also known as the Stroke Belt, has the highest prevalence of hypertension compared to other regions of the US.[21] Many counties located in the southeastern US have an age-adjusted prevalence of hypertension ranging from 42-59%; in comparison, a majority of counties in western US have hypertension prevalence 20-33%.[22] This disparity is further seen in southern states with Black women having higher risk of developing hypertension compared to Black men.[23]

There were over one million PLWH within the US in 2018, of whom women accounted for 19% of incident HIV diagnoses.[24] Furthermore, over half of newly diagnosed HIV cases were among people living in the South compared to other regions, especially in urban areas.[25] Several southern states have a mortality rate that is 3-times higher than non-southern states for PLWH.[25]

Blood pressure readings among people with obesity

Recording proper BP measurements is crucial in correctly identifying cases of hypertension and monitoring hypertension control. The prevalence of obesity has

increased in the US to 42% in 2017-2018.[26] Appropriate BP cuff fitting can be difficult for individuals with obesity because the cuffs provided by manufacturers are too small for individuals with large upper arm circumference (>40 cm) or because the shape of the cuffs do not fit people with conically shaped upper arms. When smaller cuff sizes are used on a participant's upper arm that is greater than the recommended range, then overestimation of BP can occur leading to an artificial increase in hypertension diagnoses.[27-29] In instances where brachial cuffs are not appropriate to obtain proper BP readings, radial forearm cuffs may be used as an alternative because the gold standard of using intravenous approach is too invasive.[30,31]

Significance

Since medication efficacy and tolerability for HIV have improved over time, PLWH have a life expectancy that approaches that of PLWOH.[32,33] However, PLWH live more of those years with chronic comorbidities, including hypertension, that increase their risk of developing CVD.[32,34-37] Identification of racial and ethnic disparities in hypertension can help direct treatment and control of hypertension, such as access to insurance/medication and management of multiple stressors (i.e., structural barriers to care and intersectionality), to help prevent downstream factors that affect health disparities. Few research studies have investigated the association of race/ethnicity and hypertension control among PLWH.

In addition, it is vital to properly obtain BP measurements to accurately diagnose hypertension, especially among people with obesity. Since radial BP on average is higher than brachial BP, a regression equation to harmonize BP readings is necessary in order to

improve diagnostic accuracy.[28,38] This harmonization can help inform hypertension research and clinical practice among individuals with obesity.

DISPARITIES IN HYPERTENSION PREVALENCE, AWARENESS, TREATMENT, AND CONTROL AMONG WOMEN LIVING WITH AND WITHOUT HIV IN THE US SOUTH

by

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Abstract:

Background: Hypertension-related diseases are major causes of morbidity among women living with HIV. We evaluated cross-sectional associations of race/ethnicity and HIV infection with hypertension prevalence, awareness, treatment, and control.

Methods: Among women recruited into Southern sites of the Women's Interagency HIV Study (2013-2015), hypertension was defined as (1) systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg according to clinical guidelines when data were collected, (2) self-report of hypertension, or (3) use of antihypertensive medication. Awareness was defined as self-report of hypertension, and treatment was self-report of any antihypertensive medication use. Blood pressure control was defined as <140/90 mmHg at baseline. Prevalence ratios for each hypertension outcome were estimated through Poisson regression models with robust variance estimators adjusted for sociodemographic, behavioral, and clinical risk factors.

Results: Among 712 women, 56% had hypertension and 83% were aware of their diagnosis. Of those aware, 83% were using antihypertensive medication, and 63% of those treated had controlled hypertension. In adjusted analyses, non-Hispanic White and Hispanic women had 31% and 48% lower prevalence of hypertension than non-Hispanic Black women, respectively. Women living with HIV who had hypertension were 19% (*P*= .04) more likely to be taking antihypertension medication when compared with women living without HIV.

Conclusions: In this study population of women living with and without HIV in the US South, the prevalence of hypertension was lowest among Hispanic women and highest

among non-Hispanic Black women. Despite similar hypertension prevalence, women living with HIV were more likely to be taking antihypertensive medication when compared with women living without HIV.

Introduction:

Nearly 50% of US adults aged > 18 years have hypertension according to the 2017 definition endorsed by the American College of Cardiology and the American Heart Association (≥130/80 mmHg).[1,2] Hypertension was the highest-ranked cause of death globally in 2019, accounting for 20% of deaths among women.[3] Blood pressure control can improve quality of life, reduce cardiovascular disease (CVD) events, and increase life expectancy.[3-5] However, only 53% of US women with hypertension have controlled blood pressure.[6] Of those with uncontrolled hypertension, 50% use antihypertensive medication.[1]

Non-Hispanic (NH) Black women have disproportionally high rates of hypertension mortality within the US as compared with NH White and Hispanic women.[1,7-9] The prevalence of hypertension in NH Black, NH White, and Hispanic US women ≥20 years old was 58%, 41%, and 41%, respectively, in 2015 to 2018.[8] NH Black adults were more likely to be aware and treated for hypertension than NH White adults in 2018.[9] Despite higher antihypertensive treatment rates among those with hypertension, Black individuals had the highest prevalence of uncontrolled hypertension among the 3 groups.[1,10] These disparities in hypertension outcomes may extend to persons living with HIV, who often experience intersectional stigma and discrimination[11]; few studies have evaluated the hypertension treatment cascade among women living with HIV (WLWH). Because of the contribution of hypertension-related diseases to morbidity, management of hypertension has emerged as a priority among WLWH, who have a lifetime CVD risk of 44%.[12] Similar to the geographical distribution of hypertension within the United

States, people in the South experience the greatest proportion of new HIV diagnoses when compared with other regions.[13] Several Southern states, including Alabama, Georgia, Florida, Mississippi, and North Carolina, have a mortality rate for persons living with HIV that is 3 times higher than that of non-Southern states.[13] Persons living with HIV have a higher prevalence of hypertension than those living without HIV.[14-16] However, when compared with demographically similar women living without HIV (WLWOH), WLWH typically have increased access to health care and more regular interaction with physicians, which could lead to improved hypertension awareness, treatment, and control.[17,18]

The goal of this study was to evaluate cross-sectional associations between race/ethnicity and prevalence, awareness, treatment, and control of hypertension among women in the South participating in the Women's Interagency HIV Study (WIHS). We also evaluated associations between HIV and prevalence, awareness, treatment, and control of hypertension. Our study was designed to test 2 hypotheses: (1) prevalence, awareness, and treatment of hypertension would be higher and control of hypertension would be lower in NH Black women vs other groups, and (2) WLWH would have a higher prevalence as well as higher awareness, treatment, and control of hypertension in comparison with sociodemographically similar WLWOH.

Methods:

Population:

WIHS was created by the US National Institutes of Health in 1993 to investigate HIV among women and has been described in detail.[19] WLWH and WLWOH

sociodemographically matched to WLWH participated in twice-yearly study visits where behavioral and clinical data were collected. WIHS merged with the Multicenter AIDS Cohort Study (MACS) in 2019 to create the MACS/WIHS Combined Cohort Study (MWCCS), which has also been described.[20]

The current study included cis-gender women who were recruited into WIHS between 2013 and 2015 as part of the Southern expansion that enrolled women in the following cities: Atlanta, Georgia; Miami, Florida; Birmingham, Alabama/Jackson, Mississippi; and Chapel Hill, North Carolina (n=845). Women from non-Southern sites were enrolled in the WIHS in different recruitment waves that spanned from 1993 to 2015. Women enrolled in Southern sites were recruited only in the last recruitment wave; therefore, analyses were limited to women at Southern sites to help control for major secular trends in hypertension outcomes. Inclusion criteria for WLWH were documentation of a reactive HIV serology, prescription of highly active antiretroviral therapy (ART), or prescription of non-highly active ART during pregnancy.[19] Inclusion criteria for WLWOH were at least 1 of the following high-risk exposures within the last 5 years: sexually transmitted infection, injection drug use, sex with a man who had HIV infection, or sex with multiple men.[19] For the current analyses, participants were excluded if they were missing data needed to determine prevalence, awareness, treatment, and control of hypertension, as were participants missing data on race/ethnicity, HIV status, and covariates.

WIHS participants provided written informed consent, and participating sites received institutional review board approval before enrolling participants. This analysis received approval by the MWCCS executive committee and University of Alabama at

Birmingham institutional review board. Data necessary to replicate these analyses are available from MWCCS (https://statepi.jhsph.edu/mwccs/work-with-us/, mwccs@jhu.edu). The lead Author (J. B.) had full access to all data in her study and takes full responsibility for their integrity and analysis.

Outcomes:

Blood pressure was measured with an automated monitor (Dinamap Procare Series; GE Medical Systems) for standardization. Proper cuff size was determined by measuring the arm circumference of the midpoint between the shoulder and the elbow. Participants were seated with both feet flat on the floor for 5 minutes before the first reading. Three blood pressure readings were obtained with 1-minute intervals in between. Blood pressure medication use was assessed through a combination of self-report, review of pill bottles, and medication lists. The outcomes of interest were prevalence, awareness, treatment, and control of hypertension at the baseline study visit. Participants were considered to have hypertension if their mean systolic or diastolic blood pressure was ≥140/90 mmHg at the baseline visit or they reported a medical history of hypertension or use of antihypertensive medication. We chose this definition because the recommended threshold to define hypertension was ≥140/90 mmHg when baseline data were collected[1]; the diagnostic criterion for hypertension diagnosis was revised to ≥130/80 mmHg in 2017.[21] Awareness was defined by participants with hypertension knowing the status of their hypertension diagnosis. Participants were asked, “Have you ever had high blood pressure or hypertension that required medical care?” For those aware of hypertension, participants were considered to be undergoing treatment for it if they were currently

taking antihypertensive medication, which was self-reported and verified through review of medical records with participants. Among participants treated for hypertension, control of hypertension was defined as mean systolic and diastolic blood pressure <140/90 mmHg.

Main comparisons:

Our primary comparisons were among women of different race/ethnicity. Hispanic ethnicity was recorded for participants who gave an affirmative response to the question "Are you of Hispanic (Spanish) or Latina origin?" Race was self-reported as White, Black, Asian, Pacific Islander, American Indian/Alaskan, and other. Due to the small sample size of some groups, we categorized race/ethnicity as Hispanic (of any race), NH Black, and NH White. We conducted only descriptive analyses for women who reported race/ethnicity identities other than Hispanic (of any race), NH Black, and NH White because of small sample sizes. We also compared women living with and without HIV at baseline visit. A sensitivity analysis was explored by HIV status, defined as negative, suppressed viral load (<20 copies/mL), and unsuppressed viral load.

Covariates:

All covariates were captured at baseline visit. Sociodemographic, behavioral, and clinical covariates were selected by known or hypothesized associations with race/ethnicity, HIV, and hypertension outcomes that could lead to confounding. The sociodemographic factors that we considered were age, highest education level, and health insurance, which were all captured through questionnaires. Education was

categorized as less than high school, high school graduate, some college, and college graduate or higher. Health insurance was categorized as uninsured, Medicaid only, AIDS Drug Assistance Program only, and other, which includes > 1 type of insurance. The behavioral factors were smoking status (never, current, or former), current alcohol use, and substance use. Alcohol use was categorized as none, moderate (1-7 drinks/wk), and heavy (>7 drinks/wk) according to the National Institute on Alcohol Abuse and Alcoholism guidelines for women.[22] Substance use was categorized as ever use of intravenous drugs, nonintravenous drugs (crack, cocaine, heroin, or methadone) other than marijuana, marijuana only, and none. The clinical risk factors in the analyses were body mass index (kg/m^2; underweight/normal, <25; overweight, 25 to <30; obesity, ≥30), diabetes, estimated glomerular filtration rate (based on Chronic Kidney Disease Epidemiology Collaboration definition with race)[23], hepatic fibrosis[24], aspartate aminotransferase/platelet ratio, hepatitis C virus infection status, depressive symptoms per the Center for Epidemiologic Studies-Depression scale, and history of CVD. Diabetes was defined as fasting glucose ≥126 mg/dL, hemoglobin A_{1C} ≥6.5%, confirmed self-report diagnosis, or ever self-reported antidiabetic medication. A participant was considered to have depressive symptoms if the Center for Epidemiologic Studies-Depression score was ≥16.[25] Self-reported history of CVD was defined as heart attack, stent, stroke, chest pain, or hospitalization for heart condition. HIV-specific characteristics consisted of duration of ART in years, CD4 count, current ART, and history of AIDS diagnosis (yes/no). ART usage at baseline was categorized as none, regimen including integrase inhibitors, and regimen not including integrase inhibitors due to known CVD risk with integrase inhibitors.[26]

Statistical methods:

We first described baseline characteristics of study participants by race/ethnicity and HIV status with mean (SD) or number (percentage). This cross-sectional study estimated prevalence ratios (PRs) for each hypertension outcome through Poisson regression models with robust variance estimators.[27] The crude PR model for our main comparison included only race/ethnicity (model 1). The fully adjusted model (model 2) comprised sociodemographic factors, behavioral factors, and clinical risk factors. HIV-related variables (current ART usage, duration of ART, and history of AIDS diagnosis) were included by creating interaction terms with HIV status. The crude PR model for our secondary comparison consisted only of HIV status (model 1). The fully adjusted model (model 2) added sociodemographic factors, behavioral factors, and clinical risk factors. The fully adjusted model did not include duration of ART, AIDS diagnosis, or ART regimen because these variables applied only to persons living with HIV.

We conducted a sensitivity analysis using the 2017 American College of Cardiology/American Heart Association definition of hypertension (≥130/80 mmHg) and hypertension control (<130/80 mmHg).[21] We conducted the following exploratory analyses: multiple imputation by chained equations to account for missing data for covariates; HIV status further categorized as negative, suppressed viral load, and unsuppressed viral load; comparison of race/ethnicity among WLHIV; and race categorized as Black and non-Black. The following covariates had missing data: health insurance, alcohol use, body mass index, estimated glomerular filtration rate, hepatic

fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C virus infection status, depression, duration of ART, and CD4 count.

Results:

In total, 845 women were recruited into the Southern sites. We excluded 2 participants who transferred into the Southern sites. In the primary analyses, participants who reported Asian/Pacific Islander, American Indian/Alaskan, and other race/ethnicity were excluded because the number of participants was too small to draw conclusions (n=15). The hypertension outcomes for these individuals are described in Supplementary Figure 1. Participants missing blood pressure measurements (n=3) and data on covariates (n=113) were also excluded (Supplementary Figure 2). See Supplementary Table 1 for characteristics of those excluded.

Our final sample included 712 women, of whom 602 (84%) were NH Black, 70 (10%) were NH White, and 40 (6%) were Hispanic. There were 493 (69%) WLHIV. Hispanic WLWH had the highest prevalence of history of AIDS at the time of study entry (13%) when compared with NH Black and NH White women (7% and 9%, respectively; Table 1). NH White and Hispanic women each had a lower prevalence of obesity and diabetes when compared with NH Black women. Nearly three-quarters of WLWH had suppressed viral loads; 62% were taking non-integrase inhibitors; and 40% had only Medicaid, as opposed to 47% of WLWOH who were uninsured. See Table 1 for the summary of the remaining characteristics.

Within our sample, 401 (56%) women had hypertension, and 331 (83%) with hypertension were aware of their diagnosis. Of those aware of their hypertension status,

83% were currently taking antihypertensive medication, and 63% of women who were treated for hypertension had it under control. The prevalence of hypertension was greater for NH Black women (60%) than for NH White and Hispanic women (43% and 25%, respectively; Figure 1). After adjustment for sociodemographic factors, behavioral factors, and clinical risk factors, NH White and Hispanic women had a significantly lower prevalence of hypertension than NH Black women (PR, 0.69 [95% CI, .54–.90]; PR, 0.52 [95% CI, .32–.85]; *P*< .0001; Table 2). Associations were similar in the sensitivity analysis with hypertension defined as ≥130/80 mmHg (Supplementary Table 2). Sensitivity analysis with multiple imputation by chained equations for missing covariates and race categorized as Black/non-Black showed equivalent results as Table 2 (Supplementary Tables 3 and 4). Among WLWH, NH White and Hispanic women had a lower prevalence of hypertension than NH Black women (PR, 0.75 [95% CI, .56–.99]; PR, 0.56 [95% CI, .32–.98]; *P*= .0058; Supplementary Table 5).

The proportion of awareness was higher among NH Black women (84%) than among NH White and Hispanic women (73% and 70%, respectively). The proportion of controlled hypertension was lower for NH Black women (62%) vs NH White and Hispanic women (74% and 100%; Figure 1), but hypertension control among Hispanic women was significantly higher than among Black women in unadjusted and adjusted analyses, although this was based on a small number of Hispanic women (Table 2).

Figure 2 shows the proportions of hypertension, awareness, treatment, and control by HIV status. Numerically, the proportions of all hypertension outcomes were higher among WLWH than WLWOH before confounder adjustment. For example, WLWH had higher proportions of antihypertension treatment compared to WLWOH (88% and 71%,

respectively), and this association persisted in adjusted analyses (PR, 1.19 [95% CI, 1.01–1.40]; *P*= .0353; Table 3). WLWH also had a higher prevalence of hypertension control (65%) vs WLWOH (58%), although this difference was not statistically significant in adjusted analyses. Further unadjusted exploratory analyses showed that WLWOH were less likely to be taking antihypertensive medication when compared with women with viral suppression (PR, 0.81 [95% CI, .70–.93]; *P*= .0098; Supplementary Table 6). Multiple imputation by chained equations for missing covariates and hypertension defined as ≥ 130/80 mmHg showed similar results as Table 3 (Supplementary Tables 7 and 8). See Supplementary Table 9 for associations between covariates and hypertension outcomes.

Discussion:

In the current study of women enrolled in WIHS sites in the South, Hispanic women had 48% and NH White women had 30% lower prevalence of hypertension when compared with NH Black women after adjusting for covariates. Additionally, we found that Hispanic women who were prescribed antihypertensive medication were more likely to have controlled hypertension than NH Black women. These results are similar to findings from the National Health and Nutrition Examination Survey, which is representative of the noninstitutionalized civilian population of the United States.[28] Among participants in the US AIDS Drug Assistance Program for prescription assistance among persons living with HIV in WIHS, Black women were more likely to use antihypertension medication than NH White women and other ethnicities.[29] This suggests that the same contextual factors that lead to greater hypertension prevalence and less

control among Black Americans generally are also drivers of hypertension disparities among WLWH and sociodemographically matched WLWOH.

WLWH were 19% more likely to be taking antihypertensive medication when compared with sociodemographically matched WLWOH. The overall adjusted PRs for each hypertension outcome were higher among WLWH than WLWOH but nonsignificant, with relatively wide confidence intervals. A 2021 study examining the association between hypertension and HIV infection among women in the WIHS cohort showed similar nonsignificant results.[30] In contrast, a global meta-analysis of cross-sectional studies found that persons living with HIV had a higher prevalence of hypertension than persons living without HIV.[31,32] Hypertension and suboptimal treatment of hypertension may share risk factors with HIV, such as poverty, racism, and lack of access to health care. Associations between HIV infection and hypertension outcomes in broadly defined study populations may be in part due to residual confounding from sociodemographic and behavioral risk factors for HIV that overlap with risk factors for hypertension. Although our sample size is relatively small, women in WIHS have similar demographic and behavioral factors, regardless of HIV status. This may explain the less dramatic differences in hypertension outcomes between WLWH and WLWOH in this population when compared with other study populations.

Clinical implications of controlled hypertension include a lower risk of the following conditions as compared with uncontrolled hypertension: CVD, congestive heart failure, stroke, myocardial infarction, renal disease, and cognitive dysfunction.[33,34] When compared with lower adherence, prolonged adherence of antihypertension medication can lower risk of adverse cardiovascular events by 38%.[35] When compared with WLWOH,

WLWH have increased risk of hypertension-related events, such as myocardial infarction, coronary revascularization, stroke, and heart failure.[36,37] Accordingly, screening for and treatment of hypertension are imperative for reducing hypertension-related morbidity and mortality among WLWH. Research on adherence to antihypertensive medications, lifestyle interventions to manage blood pressure, optimal antihypertensive medication regimens, and integration of blood pressure management into other types of health care for WLWH and women at risk for HIV can help to address the disparities identified in this study and similar studies.

This analysis addresses a gap in literature on the hypertension cascade of prevalence, awareness, treatment, and control among WLHIV and women at risk of HIV. The study had several strengths, such as standardized measurements across sites and generalizability of results among WLWH and sociodemographically matched women in the Southern United States. We recognize that this study is not without its limitations. Due to the nature of self-report, bias can occur in participants' answers to questions that are not verified by medical records or laboratory results. Since this is a cross-sectional analysis, we could not evaluate lifestyle interventions (eg, low-salt diet or weight loss) that may be used as first-line therapy for hypertension before initiating antihypertensive medications. WIHS did not collect information to determine adherence of antihypertensive medication for this study population at baseline. Participants who were missing data to determine race/ethnicity and covariates were excluded, which limited our sample size. Few women who were identified as races other than Black or White were included, preventing us from conducting in-depth analyses among these women. Additionally, guidelines for diagnosis of hypertension require that blood pressure be

elevated across several measurement occasions; we relied on blood pressure measured at a single baseline study visit, which may have led to under- or overestimation of the prevalence of hypertension.

The patterns of hypertension prevalence, awareness, treatment, and control by race/ethnicity in our study of WLWH and women vulnerable to HIV acquisition generally aligned with prior studies in the US general population. We did not find statistically significant differences between HIV status and hypertension prevalence, awareness, or control, possibly because participants in WIHS living with and without HIV are sociodemographically matched and because of the small sample size. WLWH were more likely to be treated for hypertension than WLWOH, which may reflect better access and more frequent care associated with HIV treatment. The high prevalence of hypertension and substantial proportion of individuals whose hypertension was not controlled, particularly among Black women, indicates a need for continuing efforts to diagnosis and effectively treat hypertension in this population.

Supplementary data: Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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Table 1. Characteristics of study population for women enrolled at Southern sites of the Women's Interagency HIV Study (N=712)

	Overall (N=712)	NH Black (n=602)	NH White (n=70)	Hispanic (n=40)	WLWH (n=493)	WLWOH (n=219)
Baseline age, y	43.2 ± 9.4	43.3 ± 9.5	44.0 ± 9.1	40.8 ± 9.1	43.8 ± 9.2	42.0 ± 9.7
Race/ethnicity						
NH Black	602 (84.6)	---	---	---	417 (84.6)	185 (84.5)
NH White	70 (9.8)	---	---	---	49 (9.9)	21 (9.6)
Hispanic	40 (5.6)	---	---	---	27 (5.5)	13 (5.9)
Education						
Less than high school	214 (30.1)	181 (30.1)	17 (24.3)	16 (40.0)	148 (30.0)	66 (30.1)
High school graduate	222 (31.2)	179 (29.7)	26 (37.1)	17 (42.5)	166 (33.7)	56 (25.6)
Some college	226 (31.7)	197 (32.7)	23 (32.9)	6 (15.0)	145 (29.4)	81 (37.0)
College graduate or higher	50 (7.0)	45 (7.5)	4 (5.7)	1 (2.5)	34 (6.9)	16 (7.3)
Health insurance						
Uninsured	166 (23.3)	132 (21.9)	20 (28.6)	14 (35.0)	63 (12.8)	103 (47.0)
Medicaid only	261 (36.7)	226 (37.5)	24 (34.3)	11 (27.5)	198 (40.2)	63 (28.8)
ADAP only	107 (15.0)	84 (14.0)	11 (15.7)	12 (30.0)	107 (21.7)	0 (0.0)
Other[a]	178 (25.0)	160 (26.6)	15 (21.4)	3 (7.5)	125 (25.4)	53 (24.2)
Smoking status						
Never	289 (40.6)	250 (41.5)	17 (24.3)	22 (55.0)	217 (44.0)	72 (32.9)
Former	93 (13.1)	76 (12.6)	14 (20.0)	3 (7.5)	71 (14.4)	22 (10.1)
Current	330 (46.4)	276 (45.9)	39 (55.7)	15 (37.5)	205 (41.6)	125 (57.1)
Alcohol use,[b] %						
None	336 (47.2)	278 (46.2)	34 (48.6)	24 (60.0)	245 (49.7)	91 (41.6)
Moderate	251 (35.3)	219 (36.4)	22 (31.4)	10 (25.0)	181 (36.7)	70 (32.0)
Heavy	125 (17.6)	105 (17.4)	14 (20.0)	6 (15.0)	67 (13.6)	58 (26.5)
Substance use						
None	233 (32.7)	197 (32.7)	13 (18.6)	23 (57.5)	178 (36.1)	55 (25.1)
Marijuana only	117 (16.4)	99 (16.5)	14 (20.0)	4 (10.0)	74 (15.0)	43 (19.6)
Nonintravenous drug use	316 (44.4)	278 (46.2)	29 (41.4)	9 (22.5)	210 (42.6)	106 (48.4)
Intravenous drug use	46 (6.5)	28 (4.7)	14 (20.0)	4 (10.0)	31 (6.3)	15 (6.9)
Body mass index,[c] %						
Underweight/ Normal	123 (17.3)	95 (15.8)	18 (25.7)	10 (25.0)	88 (17.9)	35 (16.0)
Overweight	163 (22.9)	130 (21.6)	18 (25.7)	15 (37.5)	122 (24.8)	41 (18.7)
Obesity	426 (59.8)	377 (62.6)	34 (48.6)	15 (37.5)	283 (57.4)	143 (65.3)
History of CVD,[d] %	64 (9.0)	56 (9.3)	5 (7.1)	3 (7.5)	41 (8.3)	23 (10.5)
Diabetes,[e] %	84 (11.8)	76 (12.6)	5 (7.1)	3 (7.5)	56 (11.4)	28 (12.8)
eGFR	100.8 ± 23.7	102.3 ± 23.8	86.4 ± 22.2	103.4 ± 16.8	98.5 ± 24.5	106.1 ± 21.1
Hepatic fibrosis	1.06 ± 1.0	1.1 ± 1.0	1.1 ± 0.7	1.0 ± 0.6	1.1 ± 0.8	0.98 ± 1.2
APRI	0.3 ± 0.4	0.3 ± 0.4	0.3 ± 0.4	0.3 ± 0.2	0.3 ± 0.3	0.3 ± 0.6
Hepatitis C	84 (11.8)	62 (10.3)	19 (27.1)	3 (7.5)	56 (11.4)	28 (12.8)
Depressive symptoms[f]	327 (45.9)	272 (45.2)	37 (52.9)	18 (45.0)	217 (44.0)	110 (50.2)
HIV status						
Negative	219 (30.8)	185 (30.7)	21 (30.0)	13 (32.5)	---	219 (100.0)
Suppressed[g]	363 (51.0)	308 (51.2)	39 (55.7)	16 (40.0)	363 (73.6)	---
Unsuppressed	130 (18.3)	109 (18.1)	10 (14.3)	11 (27.5)	130 (26.4)	---

Current ART usage						
None	28 (5.7)	25 (6.0)	2 (4.1)	1 (3.7)	28 (5.7)	---
INSTIs	162 (32.9)	130 (31.2)	22 (44.9)	10 (37.0)	162 (32.9)	---
Non-INSTIs	303 (61.5)	262 (62.8)	25 (51.0)	16 (59.3)	303 (61.5)	---
Duration of ART, y	4.1 ± 2.7	4.1 ± 2.7	3.6 ± 2.4	4.3 ± 3.1	4.1 ± 2.7	---
CD4 count, cells/μL	752.5 ± 414.6	746.2 ± 405.6	835.2 ± 462.7	702.3 ± 450.9	601.9 ± 319.4	1091.6 ± 404.3
AIDS diagnosis	54 (7.6)	43 (7.1)	6 (8.6)	5 (12.5)	54 (11.0)	---

Data are presented as mean ± SD or No. (%).

Abbreviations: ADAP, AIDS Drug Assistance Program; APRI, aspartate aminotransferase/platelet ratio; ART, antiretroviral therapy; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; INSTI, integrase inhibitor; NH, non-Hispanic; WLWH, women living with HIV; WLWOH, women living without HIV.

[a]Other includes private, Medicare, combination of insurances, and other insurance.

[b]Rank based on none, moderate (1-7 drinks/wk), and heavy (>7 drinks/wk) according to National Institute on Alcohol Abuse and Alcoholism guidelines for women.

[c]Body mass index (kg/m^2) defined as underweight/normal (<25), overweight (25 to <30), and obesity (≥30).

[d]History of CVD includes, myocardial infarction, hospitalization for congestive heart failure, stroke, transient ischemic attack, hospitalization for angina, or surgery on heart vessels.

[e]Diabetes defined as fasting glucose ≥126 mg/dL, hemoglobin A_{1C} ≥6.5%, confirmed self-report diagnosis, or ever self-reported anti-diabetic medication.

[f]Depressive symptoms defined Center for Epidemiologic Studies-Depression score ≥16.

[g]Cutoff for viral suppression was <20 copies/mL.

Table 2. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study

	Prevalence ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Prevalence (n=712)		**<.0001**		**<.0001**
NH Black	1 [Reference]		1 [Reference]	
NH White	0.71 (.54–.94)		0.69 (.54–.90)	
Hispanic	0.42 (.24–.72)		0.52 (.32–.85)	
Awareness (n=401)		.3273		.1097
NH Black	1 [Reference]		1 [Reference]	
NH White	0.88 (.70–1.09)		0.83 (.68–1.02)	
Hispanic	0.84 (.56–1.26)		0.84 (.59–1.17)	
Treatment (n=331)		.5253		.3477
NH Black	1 [Reference]		1 [Reference]	
NH White	1.02 (.83–1.25)		0.95 (.79–1.16)	
Hispanic	0.71 (.37–1.36)		0.72 (.43–1.19)	
Control (n=275)		.0752		.0618
NH Black	1 [Reference]		1 [Reference]	
NH White	1.19 (.89–1.58)		1.19 (.86–1.65)	
Hispanic	1.62 (1.47–1.78)		2.12 (1.52–2.96)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table 3. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study

Prevalence ratio (95% CI)				
	Model 1[a]	*P* value	Model 2[b]	*P* value
Prevalence (n=712)		.1744		.0592
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.10 (.95–1.28)		1.18 (.99–1.40)	
Awareness (n=401)		.7900		.4872
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.01 (.92–1.12)		1.05 (.92–1.19)	
Treatment (n=331)		**.0065**		**.0353**
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.21 (1.05–1.41)		1.19 (1.01–1.40)	
Control (n=275)		.3321		.4931
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.12 (.89–1.40)		1.10 (.83–1.47)	

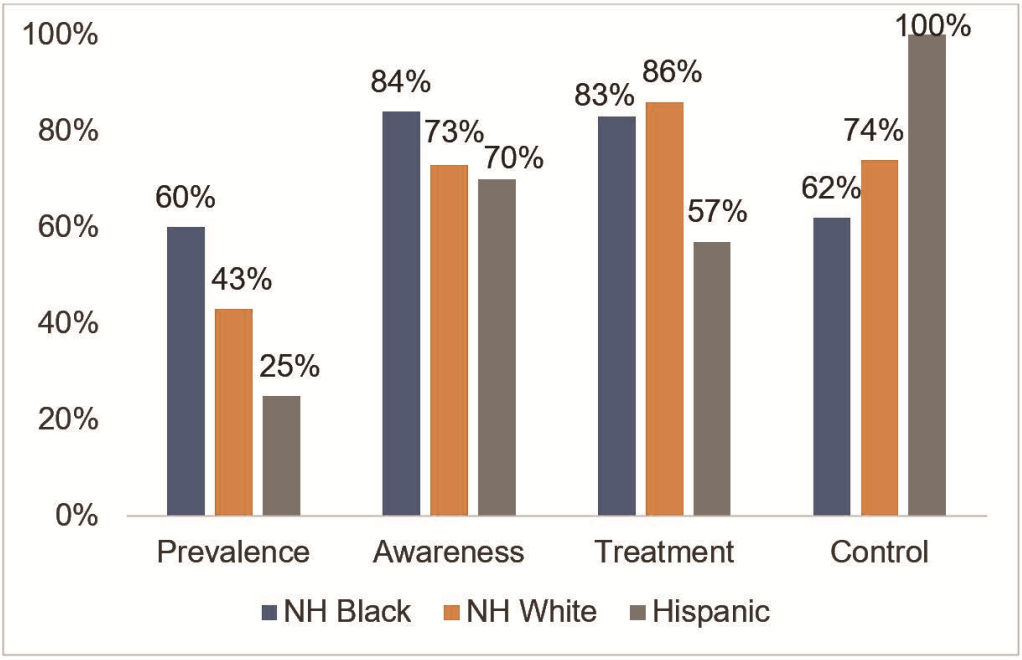
Bold type indicates significance.

Abbreviations: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: race/ethnicity, age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

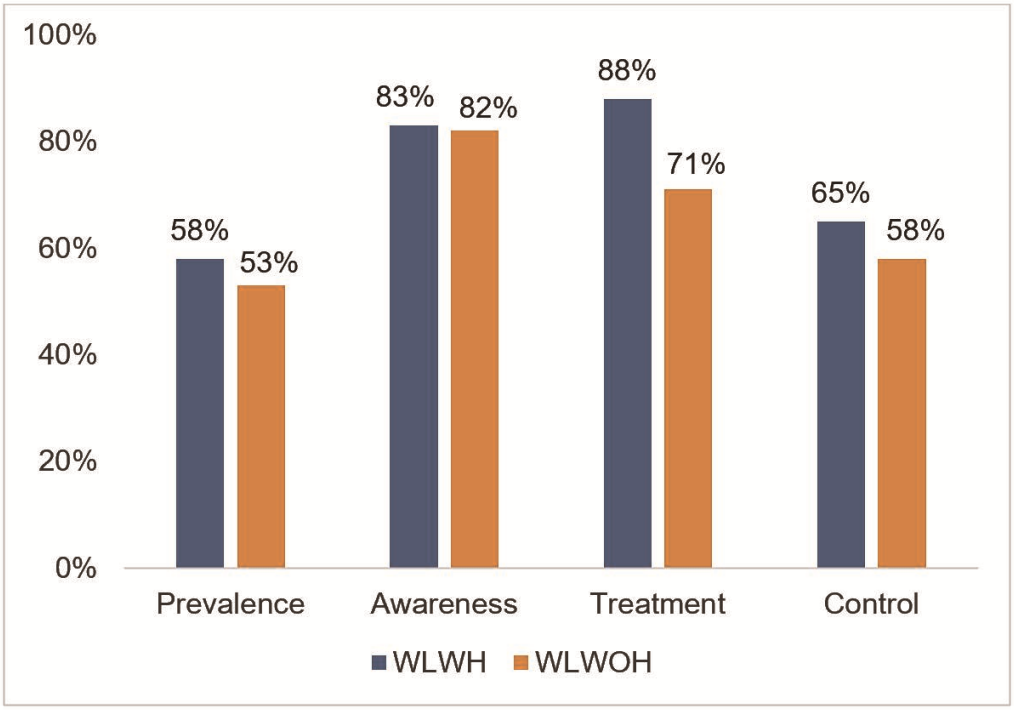
Figure 1. Proportions of hypertension outcomes by race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study (N=712).



	Prevalence	Awareness	Treatment	Control
NH Black	361/602	302/361	252/302	156/252
NH White	30/70	22/30	19/22	14/19
Hispanic	10/40	7/10	4/7	4/4

Abbreviations: NH, non-Hispanic.

Figure 2. Proportions of hypertension outcomes by HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study (N=712).



	Prevalence	Awareness	Treatment	Control
WLWH	286/493	237/286	208/237	135/208
WLWOH	115/219	94/115	67/94	39/67

Abbreviations: WLHW, women living with HIV; WLWOH, women living without HIV.

Table S1. Characteristics of study population for women enrolled at Southern sites of the Women's Interagency HIV Study included and excluded from analyses

	Included (N=712)	Excluded (N=133)
Baseline age, y	43.2 ± 9.4	42.7 ± 9.2
Race/ethnicity		
NH Black	602 (84.6)	98 (73.7)
NH White	70 (9.8)	9 (6.8)
Hispanic	40 (5.6)	11 (8.3)
Education		
Less than high school	214 (30.1)	41 (30.8)
High school graduate	222 (31.2)	44 (33.1)
Some college	226 (31.7)	35 (26.3)
College graduate or higher	50 (7.0)	13 (9.8)
Health insurance		
Uninsured	166 (23.3)	41 (31.1)
Medicaid only	261 (36.7)	34 (25.8)
ADAP only	107 (15.0)	29 (22.0)
Other[a]	178 (25.0)	28 (21.2)
Smoking status		
Never	289 (40.6)	50 (37.6)
Former	93 (13.1)	17 (12.8)
Current	330 (46.4)	66 (49.6)
Alcohol use,[b] %		
None	336 (47.2)	51 (38.6)
Moderate	251 (35.3)	49 (37.1)
Heavy	125 (17.6)	32 (24.2)
Substance use		
None	233 (32.7)	43 (32.3)
Marijuana only	117 (16.4)	28 (21.1)
Nonintravenous drug use	316 (44.4)	48 (36.1)
Intravenous drug use	46 (6.5)	14 (10.5)
BMI,[c] %		
Underweight/Normal	123 (17.3)	36 (28.6)
Overweight	163 (22.9)	34 (27.0)
Obesity	426 (59.8)	56 (44.4)
History of CVD,[d] %	64 (9.0)	16 (12.0)
Diabetes,[e] %	84 (11.8)	10 (7.5)
eGFR	100.8 ± 23.7	103.8 ± 22.4
Hepatic fibrosis	1.1 ± 1.0	1.6 ± 2.0
APRI	0.3 ± 0.4	0.4 ± 0.8
Hepatitis C	84 (11.8)	23 (17.6)
Depressive symptoms[f]	327 (45.9)	55 (43.7)

HIV status		
Negative	219 (30.8)	16 (12.0)
Suppressed[g]	363 (51.0)	26 (19.6)
Unsuppressed	130 (18.3)	91 (68.4)
Current ART usage		
None	28 (5.7)	91 (77.8)
INSTIs	162 (32.9)	4 (3.4)
Non-INSTIs	303 (61.5)	22 (18.8)
Duration of ART, y	4.1 ± 2.7	4.6 ± 3.0
CD4 count, cells/μL	752.5 ± 414.6	555.5 ± 334.6
AIDS diagnosis	54 (7.6)	8 (6.0)

Data are presented as mean ± SD or No. (%).

Abbreviations: ADAP, AIDS Drug Assistance Program; APRI, aspartate aminotransferase/platelet ratio; ART, antiretroviral therapy; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; INSTI, integrase inhibitor; NH, non-Hispanic; WLWH, women living with HIV; WLWOH, women living without HIV.

[a]Other includes private, Medicare, combination of insurances, and other insurance.

[b]Rank based on none, moderate (1-7 drinks/wk), and heavy (>7 drinks/wk) according to National Institute on Alcohol Abuse and Alcoholism guidelines for women.

[c]Body mass index (kg/m^2) defined as underweight/normal (<25), overweight (25 to <30), and obesity (≥30).

[d]History of CVD includes, myocardial infarction, hospitalization for congestive heart failure, stroke, transient ischemic attack, hospitalization for angina, or surgery on heart vessels.

[e]Diabetes defined as fasting glucose ≥126 mg/dL, hemoglobin A_{1C} ≥6.5%, confirmed self-report diagnosis, or ever self-reported anti-diabetic medication.

[f]Depressive symptoms defined Center for Epidemiologic Studies-Depression score ≥16.

[g]Cutoff for viral suppression was <20 copies/mL.

Table S2. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension (≥ 130/80 mmHg) outcomes and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study

Prevalence ratio (95% CI)				
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Prevalence (n=712)		**.0010**		**.0114**
NH Black	1 [Reference]		1 [Reference]	
NH White	0.80 (.64–1.00)		0.80 (.65–.99)	
Hispanic	0.58 (.40–.86)		0.70 (.49–1.01)	
Awareness (n=464)		**.0244**		**.0053**
NH Black	1 [Reference]		1 [Reference]	
NH White	0.79 (.60–1.04)		0.73 (.56–.94)	
Hispanic	0.59 (.34–1.04)		0.62 (.37–1.04)	
Treatment (n=331)		.5253		.3477
NH Black	1 [Reference]		1 [Reference	
NH White	1.02 (.83–1.25)		0.95 (.79–1.16)	
Hispanic	0.71 (.37–1.36)		0.72 (.43–1.19)	
Control (n=275)		.3546		.1697
NH Black	1 [Reference]		1 [Reference]	
NH White	0.82 (.42–1.62)		0.72 (.34–1.54)	
Hispanic	1.95 (1.08–3.50)		2.94 (1.34–6.43)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S3. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity with imputed values for women enrolled at Southern sites of the Women's Interagency HIV Study

Prevalence ratio (95% CI)				
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Prevalence (n=825)		**<.0001**		**.0001**
NH Black	1 [Reference]		1 [Reference]	
NH White	0.72 (.56–.94)		0.69 (.54–.89)	
Hispanic	0.46 (.29–.72)		0.56 (.37–.87)	
Awareness (n=461)		.4764		.1890
NH Black	1 [Reference]		1 [Reference]	
NH White	0.89 (.72–1.09)		0.85 (.70–1.04)	
Hispanic	0.95 (.72–1.25)		0.88 (.67–1.16)	
Treatment (n=378)		.5807		.2425
NH Black	1 [Reference]		1 [Reference	
NH White	0.96 (.77–1.21)		0.96 (.80–1.15)	
Hispanic	0.81 (.51–1.26)		0.67 (.41–1.08)	
Control (n=308)		.4071		.1625
NH Black	1 [Reference]		1 [Reference]	
NH White	1.21 (.93–1.59)		1.22 (.90–1.65)	
Hispanic	1.15 (.72–1.86)		1.58 (.90–2.76)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S4. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity defined as Black and non-Black for women enrolled at Southern sites of the Women's Interagency HIV Study

Prevalence ratio (95% CI)				
	Model 1[a]	*P* value	Model 2[b]	*P* value
Prevalence (n=723)		**<.0001**		**.0001**
Black	1 [Reference]		1 [Reference]	
Non-Black	0.65 (.51–.82)		0.67 (.54–.84)	
Awareness (n=406)		.1987		.0665
Black	1 [Reference]		1 [Reference]	
Non-Black	0.89 (.74–1.07)		0.86 (.73–1.02)	
Treatment (n=335)		.5176		.2048
Black	1 [Reference]		1 [Reference]	
Non-Black	0.94 (.76–1.15)		0.89 (.73–1.07)	
Control (n=278)		.1387		.1201
Black	1 [Reference]		1 [Reference]	
Non-Black	1.22 (.96–1.56)		1.27 (.96–1.67)	

Bold type indicates significance.

[a]Race only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S5. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity among women with HIV enrolled at Southern sites of the Women's Interagency HIV Study

Prevalence ratio (95% CI)				
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Prevalence (n=493)		**.0018**		**.0058**
NH Black	1 [Reference]		1 [Reference]	
NH White	0.80 (.60–1.08)		0.75 (.56–.99)	
Hispanic	0.42 (.22–.81)		0.56 (.32–.98)	
Awareness (n=286)		.3108		.1105
NH Black	1 [Reference]		1 [Reference]	
NH White	0.84 (.65–1.09)		0.82 (.61–1.03)	
Hispanic	0.85 (.53–1.36)		0.82 (.56–1.22)	
Treatment (n=237)		.5895		.3756
NH Black	1 [Reference]		1 [Reference]	
NH White	0.97 (.78–1.22)		0.95 (.77–1.17)	
Hispanic	0.71 (.35–1.45)		0.70 (.40–1.23)	
Control (n=208)				
NH Black	1 [Reference]	.2184	1 [Reference]	.1995
NH White	1.04 (.71–1.51)		1.01 (.68–1.49)	
Hispanic	1.56 (1.40–1.73)		2.05 (1.37–3.06)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S6. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study

	Prevalence ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Prevalence (n=712)		.3806		.1679
Suppressed	1 [Reference]		1 [Reference]	
Unsuppressed	0.97 (.82–1.16)		0.99 (.84–1.16)	
Negative	0.90 (.77–1.05)		0.85 (.71–1.01)	
Awareness (n=401)		.9587		.7852
Suppressed	1 [Reference]		1 [Reference]	
Unsuppressed	0.99 (.88–1.12)		1.00 (.88–1.13)	
Negative	0.98 (.89–1.09)		0.95 (.84–1.09)	
Treatment (n=331)		**.0098**		.0824
Suppressed	1 [Reference]		1 [Reference]	
Unsuppressed	0.92 (.79–1.06)		0.96 (.84–1.11)	
Negative	0.81 (.70–.93)		0.83 (.71–.98)	
Control (n=275)		.0966		.1073
Suppressed	1 [Reference]		1 [Reference]	
Unsuppressed	0.77 (.58–1.03)		0.76 (.57–1.02)	
Negative	0.85 (.68–1.07)		0.87 (.66–1.16)	

[a]HIV status only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV.

Table S7. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension outcomes and HIV with imputed values for women enrolled at Southern sites of the Women's Interagency HIV Study

Prevalence ratio (95% CI)				
	Model 1[a]	*P* value	Model 2[b]	*P* value
Prevalence (n=825)		.2778		.1545
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.08 (.94–1.24)		1.12 (.96–1.32)	
Awareness (n=461)		.7413		.5019
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.02 (.81–1.28)		1.03 (.92–1.19)	
Treatment (n=378)		**.0060**		**.0330**
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.22 (1.05–1.41)		1.20 (1.02–1.41)	
Control (n=308)		.2863		.3788
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.13 (.85–1.41)		1.13 (.86–1.49)	

Body type indicates significance.

Abbreviations: WLWH, women living with HIV; WLWOH: women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: race/ethnicity, age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Table S8. Unadjusted and adjusted prevalence ratios and 95% CIs for the association between hypertension (≥ 130/80 mmHg) outcomes and HIV for women enrolled at Southern sites of the Women's Interagency HIV Study

Prevalence ratio (95% CI)				
	Model 1[a]	*P* value	Model 2[b]	*P* value
Prevalence (n=712)		.1430		.0778
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.09 (.97–1.24)		1.14 (.98–1.32)	
Awareness (n=464)		.7206		.3563
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.02 (.90–1.17)		1.08 (.92–1.27)	
Treatment (n=331)		**.0065**		**.0353**
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.21 (1.05–1.49)		1.19 (1.01–1.40)	
Control (n=275)		.4082		.6085
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.16 (0.80–1.68)		1.12 (0.73–1.72)	

Bold type indicates significance.

Abbreviations: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Poisson model includes the following variables: race/ethnicity, age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Table S9. Associations of characteristics of study population for women enrolled at Southern sites of the Women's Interagency HIV Study by hypertension outcomes

	Presence hypertension (n=401)	Absence hypertension (n=311)	*P* value	Presence awareness (n=331)	Absence awareness (n=70)	*P* value	Presence treatment (n=264)	Absence treatment (n=67)	*P* value	Presence control (n=165)	Absence control (n=99)	*P* value
Baseline age, y	46.2 ± 9.0	39.4 ± 8.5	**<.001**	46.4 ± 8.8	45.2 ± 9.7	.3119	47.9 ± 8.0	40.4 ± 9.4	**<.001**	47.8 ± 7.9	48.1 ± 8.2	.7920
Race/ethnicity			**<.001**			.2051			.2872			.2586
NH Black	361 (90.0)	241 (77.5)		302 (91.2)	59 (84.3)		242 (91.7)	60 (89.6)		148 (89.7)	94 (95.0)	
NH White	30 (7.5)	40 (12.9)		22 (6.7)	8 (11.4)		18 (6.8)	4 (6.0)		13 (7.9)	5 (5.1)	
Hispanic	10 (2.5)	30 (9.7)		7 (2.11)	3 (4.3)		4 (1.5)	3 (4.5)		4 (2.4)	0 (0.0)	
Education			.7120			.6087			.1593			.7576
< HS	121 (30.2)	93 (29.9)		104 (31.4)	17 (24.3)		79 (29.9)	25 (37.3)		46 (27.9)	33 (33.3)	
HS graduate	123 (30.7)	99 (31.8)		98 (29.6)	25 (35.7)		75 (28.4)	23 (34.3)		50 (30.3)	25 (25.3)	
Some college	125 (31.2)	101 (32.5)		102 (30.8)	23 (32.9)		89 (33.7)	13 (19.4)		56 (33.9)	33 (33.3)	
≥College graduate	32 (8.0)	18 (5.8)		27 (8.2)	5 (7.1)		21 (8.0)	6 (9.0)		13 (7.9)	8 (8.1)	
Health insurance			.0821			.9036			**.0038**			.9602
Uninsured	94 (23.4)	72 (23.2)		78 (23.6)	16 (22.9)		53 (20.1)	25 (37.3)		32 (19.4)	21 (21.2)	
Medicaid only	142 (35.4)	119 (38.3)		118 (35.7)	24 (34.3)		94 (35.6)	24 (35.8)		58 (35.2)	36 (36.4)	
ADAP only	52 (13.0)	55 (17.7)		41 (12.4)	11 (15.7)		32 (12.1)	9 (13.4)		21 (12.7)	11 (11.1)	
Other[a]	113 (28.2)	65 (20.9)		94 (28.4)	19 (27.1)		85 (32.2)	9 (13.4)		54 (32.7)	31 (31.3)	
Smoking status			**.0337**			.2202			.7604			.0985
Never	148 (36.9)	141 (45.3)		116 (35.1)	32 (45.7)		93 (35.2)	23 (34.3)		63 (38.2)	30 (30.3)	
Former	61 (15.2)	32 (10.3)		53 (16.0)	8 (11.4)		44 (16.7)	9(13.4)		31 (18.8)	13 (13.1)	
Current	192 (47.9)	138 (44.4)		162 (48.9)	30 (42.9)		127 (48.1)	35 (52.2)		71 (43.0)	56 (56.6)	
Alcohol use,[b]			.5012			.5797			**.0248**			.8767
None	191 (47.6)	145 (46.6)		156 (47.1)	35 (50.0)		128 (48.5)	28 (41.8)		81 (49.1)	47 (47.5)	
Moderate	135 (33.7)	116 (37.3)		110 (33.2)	25 (35.7)		92 (34.9)	18 (26.9)		58 (35.2)	34 (34.3)	
Heavy	75 (18.7)	50 (16.1)		65 (19.6)	10 (14.3)		44 (16.7)	21 (31.3)		26 (15.8)	18 (18.2)	
Substance use			**.0028**			.1683			.3721			.4910
None	119 (29.7)	114 (36.7)		98 (29.6)	21 (30.0)		83 (31.4)	11 (16.4)		57 (34.6)	26 (26.3)	
Marijuana	54 (13.5)	63 (20.3)		39 (11.8)	15 (21.4)		28 (10.6)	11 (16.4)		18 (10.9)	10 (10.1)	

Non-IV use IV use	199 (49.6) 29 (7.2)	117 (37.6) 17 (5.5)		169 (51.1) 25 (7.6)	30 (42.9) 4 (5.7)		133 (50.4) 20 (7.6)	36 (53.7) 5 (7.5)		79 (47.9) 11 (6.7)	54 (54.6) 9 (9.1)	
Body mass index,[c]			**<.001**			.6381			.0778			.1458
Underweight/ normal	57 (14.2)	66 (21.2)		46 (13.9)	11 (15.7)		31 (11.7)	15 (22.4)		16 (9.7)	15 (15.2)	
Overweight	73 (18.2)	90 (28.9)		58 (17.5)	15 (21.4)		48 (18.2)	10 (14.9)		35 (21.2)	13 (13.1)	
Obese	271 (67.6)	155 (49.8)		227 (68.6)	44 (62.9)		185 (70.1)	42 (62.7)		114 (69.1)	71 (71.7)	
History of CVD,[d]	50 (12.5)	14 (4.5)	**.0002**	49 (14.8)	1 (1.43)	**.0021**	46 (17.4)	3 (4.5)	**.0077**	24 (14.6)	22 (22.2)	.1114
Diabetes,[e]	72 (18.0)	12 (3.9)	**<.001**	62 (18.7)	10 (14.3)	.3786	54 (20.5)	8 (11.9)	.1107	36 (21.8)	18 (18.2)	.4782
eGFR	97.9 ± 25.5	104.5 ± 20.7	**.0001**	96.0 ± 26.1	106.9 ± 20.3	**.0002**	93.3 ± 25.7	106.5 ± 24.9	**.0002**	94.0 ± 23.9	92.2 ± 28.6	.5927
Hepatic fibrosis	1.1 ± 1.1	1.0 ± 0.6	**.0172**	1.1 ± 1.2	1.1 ± 0.8	.7297	1.1 ± 0.9	1.1 ± 1.9	.9830	1.1 ± 1.0	1.2 ± 0.8	.2781
APRI	0.3 ± 0.5	0.3 ± 0.2	.1533	0.3 ± 0.5	0.3 ± 0.4	.6434	0.3 ± 0.3	0.4 ± 0.9	.5275	0.3 ± 0.3	0.3 ± 0.3	.1816
Hepatitis C	59 (14.7)	25 (8.0)	**.0062**	46 (13.9)	13 (18.6)	.3159	37 (14.0)	9 (13.4)	.9021	20 (12.1)	17 (17.2)	.2525
Depressive symptoms[f]	191 (47.6)	136 (43.7)	.3002	165 (49.9)	26 (37.1)	.0531	127 (48.1)	38 (56.7)	.2081	77 (46.7)	50 (50.5)	.5456
HIV status			.3771			.9581			**.0051**			.0748
Negative	115 (28.7)	104 (33.4)		94 (28.4)	21 (30.0)		65 (24.6)	29 (43.3)		37 (22.4)	28 (28.3)	
Suppressed[g]	212 (52.9)	151 (48.6)		176 (53.2)	36 (51.4)		151 (57.2)	25 (37.3)		103 (62.4)	48 (48.5)	
Unsuppressed	74 (18.5)	56 (18.0)		61 (18.4)	13 (18.6)		48 (18.2)	13 (19.4)		25 (15.2)	23 (23.2)	
Current ART usage			.3658			.6021			.8784			.5149
None	13 (4.6)	15 (7.3)		12 (5.1)	1 (2.0)		10 (5.0)	2 (5.3)		5 (3.9)	5 (7.0)	
INSTIs	92 (32.2)	70 (33.8)		77 (32.5)	15 (30.6)		66 (33.2)	11 (29.0)		41 (32.0)	25 (35.2)	
Non-INSTIs	181 (63.3)	122 (58.9)		148 (62.5)	33 (67.4)		123 (61.8)	25 (65.8)		82 (64.1)	41 (57.8)	
Duration of ART, y	4.1 ± 2.7	3.9 ± 2.7	.4121	4.2 ± 2.8	3.7 ± 2.6	.2301	4.4 ± 2.8	3.5 ± 2.3	.0592	4.3 ± 2.9	4.5 ± 2.6	.5103
CD4 count, cells/μL	751.5 ± 419.8	753.9 ± 408.4	.9380	748.5 ± 425.4	765.6 ± 394.8	.7568	750.7 ± 433.4	739.6 ± 395.6	.8496	753.1 ± 412.1	746.7 ± 468.8	.9071

AIDS diagnosis	33 (8.2)	21(6.8)	.3496	27 (8.2)	6 (8.6)	.9508	26 (9.9)	1 (1.5)	**.0025**	17 (10.3)	9 (9.1)	.5603

Data are presented as mean ± SD or No. (%).

Abbreviations: ADAP, AIDS Drug Assistance Program; APRI, aspartate aminotransferase/platelet ratio; ART, antiretroviral therapy; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; HS: high school; INSTI, integrase inhibitor; IV, intravenous; NH, non-Hispanic; WLWH, women living with HIV; WLWOH, women living without HIV.

[a]Other includes private, Medicare, combination of insurances, and other insurance.

[b]Rank based on none, moderate (1-7 drinks/wk), and heavy (>7 drinks/wk) according to National Institute on Alcohol Abuse and Alcoholism guidelines for women.

[c]Body mass index (kg/m^2) defined as underweight/normal (<25), overweight (25 to <30), and obesity (≥30).

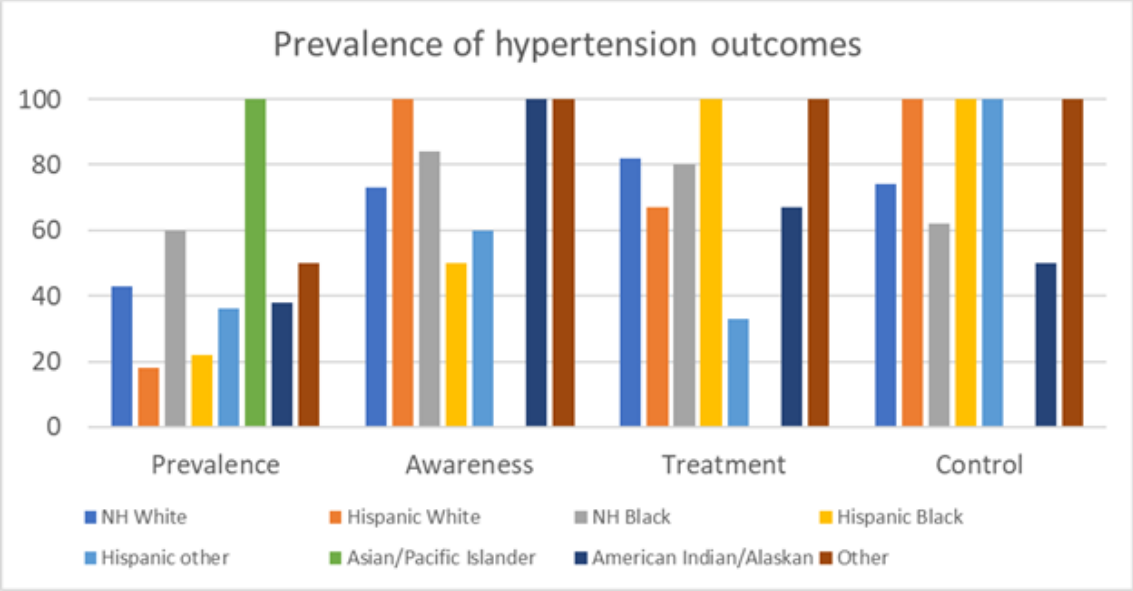
[d]History of CVD includes, myocardial infarction, hospitalization for congestive heart failure, stroke, transient ischemic attack, hospitalization for angina, or surgery on heart vessels.

[e]Diabetes defined as fasting glucose ≥126 mg/dL, hemoglobin A_{1C} ≥6.5%, confirmed self-report diagnosis, or ever self-reported anti-diabetic medication.

[f]Depressive symptoms defined Center for Epidemiologic Studies-Depression score ≥16.

[g]Cutoff for viral suppression was <20 copies/mL.

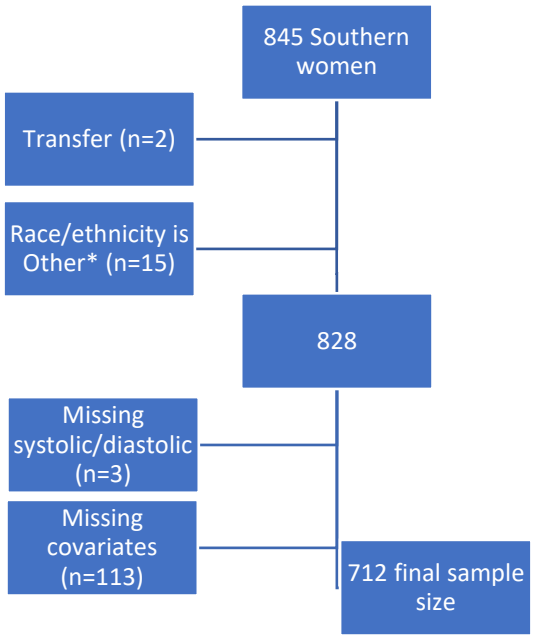
Figure S1. Proportions of hypertension outcomes by race/ethnicity for women enrolled at Southern sites of Women's Interagency HIV Study (N=723).



	Prevalence	Awareness	Treatment	Control
NH White	30/70	22/30	19/22	14/19
Hispanic White	3/17	3/3	2/3	2/2
NH Black	361/602	302/361	252/302	156/252
Hispanic Black	2/9	1/2	1/1	1/1
Hispanic other	5/14	3/5	1/3	1/1
Asian/Pacific Islander	1/1	0/1	NA	NA
American Indian/Alaskan	3/8	3/3	2/3	1/2
Other	1/2	1/1	1/1	1/1

Abbreviations: NH, non-Hispanic.

Figure S2. Flowchart of exclusion criteria for women enrolled at Southern sites of the Women's Interagency HIV Study



* Other includes Asian/Pacific Islander, American Indian/Alaskan, and other

AWARENESS, TREATMENT, AND CONTROL OF HYPERTENSION AMONG WOMEN AT RISK OR LIVING WITH HIV IN THE US SOUTH: A PROSPECTIVE STUDY

by

JESSICA P. BLAIR, MIRJAM-COLETTE KEMPF, JODIE A. DIONNE, ZENORIA CAUSEY-PRUITT, JENNI M. WISE, ELIZABETH A. JACKSON, PAUL MUNTNER, DAVID B. HANNA, JORGE R. KIZER, MARGARET A. FISCHL, IGHO OFOTOKUN, CATALINA RAMIREZ, STEPHEN GANGE, ILENE K. BRILL, EMILY B. LEVITAN

Under review in *AIDS*

Format adapted for dissertation

Abstract:

Objectives: Timely control of hypertension is vital to prevent comorbidities, especially among women living with HIV. We evaluated the association of race/ethnicity and HIV infection with incident hypertension outcomes, including awareness, treatment, and control. Participation in clinical research studies might affect the timing of adequate control after hypertension diagnosis.

Design: We evaluated cisgender women living with HIV and sociodemographically matched women living without HIV recruited into four Southern sites of the Women's Interagency HIV Study (2013-2019).

Methods: We calculated measurements of the time to four events or censoring during 6 years of follow-up: incident hypertension, hypertension awareness, hypertension treatment, and hypertension control. Hazard ratios for race/ethnicity and HIV status were calculated for each outcome using Cox proportional-hazards models adjusted for sociodemographic, behavioral, and clinical risk factors.

Results: Among 712 women, 56% were hypertensive at baseline. Forty-five percent of the remaining women who were normotensive at baseline developed incident hypertension during follow-up. Non-Hispanic White and Hispanic women had faster time to hypertension control compared to non-Hispanic Black women (p=0.01). In fully adjusted models, women living with HIV who were normotensive at baseline had faster time to treatment compared to normotensive women living without HIV (p=0.04).

Conclusions: In our study of women in the US South, non-Hispanic Black women became aware of their hypertension diagnosis more quickly than non-Hispanic White and Hispanic women but were slower to control their hypertension. Additionally, women

living with HIV more quickly treated and controlled their hypertension compared to women living without HIV.

Introduction:

With the advancement of antiretroviral therapy (ART) and other supportive care, people living with HIV (PLWH) are experiencing significantly longer lifespans compared to the early years of the HIV epidemic.[1,2] This success means that long-term management of HIV and comorbidities is increasingly important to maximize health outcomes for PLWH. A global literature review conducted in 2020 presented evidence that PLWH had higher prevalence of hypertension compared to those living without HIV.[3] Compared to women living without HIV (WLWOH), women living with HIV (WLWH) in the US have a higher risk of stroke, heart failure, and heart attack, which can be caused by hypertension and could be potentially mitigated through hypertension control.[4] Diagnosing and effectively treating hypertension among WLWH is therefore vital to prevent further debilitating disease.

There remain racial disparities in hypertension prevalence, awareness, treatment, and control among US residents. Within the US, non-Hispanic (NH) Black adults ≥25 years have a higher prevalence of hypertension and develop high blood pressure earlier in life compared to NH White and Hispanic adults of the same age.[5-7] Although hypertension prevalence decreased for White adults in the US, the proportion of Black adults with hypertension increased from 2000-2020.[8] A study conducted using National Health and Nutrition Examination Survey (NHANES) data from 1999-2016 showed awareness and treatment for hypertension were higher for Black adults compared to White adults aged 45 or older, but Black adults had significantly lower control of hypertension.[6] These disparities are especially seen in the South, where NH Black women experience higher prevalence of both hypertension and HIV infection.[9-12] Although there

are multiple health care access and behavioral components that must be in place to progress from hypertension diagnosis and awareness through effective treatment and control, to date many studies examining the hypertension treatment cascade have been cross-sectional and have not evaluated whether there are differences in time to reach each step necessary for hypertension control.

Using data from participants at four Southern sites of the Women's Interagency HIV Study (WIHS), we prospectively examined the incidence of hypertension, as well as hypertension awareness, treatment, and control among women across race and ethnicity categories. We hypothesized that NH Black women more quickly become aware of and are treated for hypertension compared to NH White and Hispanic women but are slower to control their hypertension. A secondary goal was to examine hypertension outcomes by HIV status. We hypothesized that WLWH become aware of, treat, and control hypertension faster than WLWOH.

Methods:

Population:

Beginning in 1993, the WIHS recruited US women living with HIV and sociodemographically similar women vulnerable to HIV infection to collect biological and behavioral data to better understand the HIV epidemic among women.[13] The prospective study is currently ongoing and in 2019 merged with the Multicenter AIDS Cohort Study (MACS), which primarily recruited men, to form the MACS/WIHS Combined Cohort Study (MWCCS).[14]

The current analyses included cisgender women aged 25-60 years at baseline recruited at the WIHS Southern sites in 2013-2015: Chapel Hill, NC; Atlanta, GA; Miami, FL; and Birmingham, AL/Jackson, MS (N=845). There were no participants who identified as transgender or non-binary in our analyses. To be eligible for enrollment in WIHS, women living with HIV required proof of a reactive HIV serology along with documentation of CD4 and HIV RNA quantification before starting highly active antiretroviral therapy.[13] Eligibility for WLWOH included at least one of the following within the last 5 years: sexually transmitted infection, injection drug use, sex with multiple male partners, or high-risk factors of partner(s).[13] For the current analyses, participants with a baseline visit and at least one additional visit with blood pressure measurements and information to determine awareness, treatment, or control of hypertension were included. Participants missing data on race/ethnicity, HIV status, and baseline covariates were excluded. For analysis, we created sub-cohorts of our study sample to represent participants hypertensive at baseline (≥140/90 mmHg or on antihypertensive medication) and normotensive at baseline (<140/90 mmHg and no antihypertensive medication use).

The WIHS protocol was IRB approved and participants provided written informed consent. The current analysis received approval from the UAB IRB and the MWCCS executive committee. Data necessary to replicate these analyses are available from MWCCS (https://statepi.jhsph.edu/mwccs/work-with-us/, mwccs@jhu.edu). Lead Author (JB) had full access to all data in this analysis and takes full responsibility for its integrity and data analysis.

Hypertension outcomes:

This longitudinal analysis captured data from baseline (2013-2015) to the latest available study visit (2019). Participants were seen twice a year for study visits that included interviewer administered questionnaires, biospecimen collection, and physical exams.[14] The questionnaires included demographics, medical conditions, medication use, and behaviors.[14] Blood pressure was measured during the physical exam using a standardized protocol.

Before blood pressure measurement, each participant's midarm circumference was measured to ensure proper cuff size. Participants sat quietly with their feet flat on the floor for five minutes prior to blood pressure collection. Three blood pressure measurements were captured using an automated Dinamap monitor (Dinamap Procare Series, GE Medical Systems) with one-minute intervals in between each measurement. Blood pressure medication use was obtained through self-report.

The four outcomes of interest for participants who were normotensive at baseline were time to incident hypertension, awareness, treatment, and control. For participants who were hypertensive at baseline, the outcomes of interest were time to awareness, treatment, and control of hypertension. Hypertension was defined as systolic blood pressure or diastolic blood pressure ≥140/90 mmHg or reported use of antihypertensive medication/medical history of hypertension. Incident hypertension was defined at a single time point for elevated blood pressure. At the time of baseline data collection, the recommended threshold for diagnosis of hypertension was ≥140/90 mmHg.[15] Participants were asked, "Have you ever had high blood pressure or hypertension that required medical care?" for awareness of hypertension. For participants with incident hypertension

during the analytic period, awareness was measured at subsequent visits. Treatment for hypertension was defined by the current use of antihypertensive medication, which was self-reported at every six-month visit. Control of hypertension was defined as systolic and diastolic blood pressure <140/90 mmHg.

Main comparisons:

Our primary comparison was by race/ethnicity. Race was self-reported as White, Black, Asian, Pacific Islander, American Indian/Alaskan, and other. The question, "Are you of Hispanic (Spanish) or Latina origin?" was asked to identify Hispanic ethnicity. Due to small sample size of certain racial and ethnic categories, we included NH Black, NH White, and Hispanic (of any race) women in our final analysis. We also compared Black and non-Black women, regardless of ethnicity, due to the predominance of Black women in our study sample as an exploratory analysis. Additionally, we compared WLWH and WLWOH. As another exploratory analysis, we compared WLWOH, WLWH with undetectable (<20 copies/mL) viral loads, and WLWH with detectable viral loads.

Covariates:

The covariates used in analyses were assessed during the baseline visit. Age at baseline, highest education attained (less than high school, high school graduate, some college, and college graduate or higher), and health insurance comprise the sociodemographic variables obtained through questionnaires. Health insurance was categorized as uninsured, Medicaid only, AIDS Drug Assistance Program (ADAP) only,

and other (private, Medicare, combination of insurances, or other not listed were grouped together due to small sample sizes). Behavioral variables, which were also obtained through questionnaires, included smoking status (never, former, current), current alcohol use (none, moderate 1-7 drinks/week, and heavy >7 drinks/week)[16], and lifetime substance use. Substance use was categorized as none, marijuana only, non-intravenous drugs (drugs like crack, cocaine, heroin), and intravenous drug use. Clinical risk factors included estimated glomerular filtration rate (eGFR based on CKD-EPI definition with race)[17], hepatic fibrosis (FIB-4)[18], aspartate aminotransferase/platelet ratio (APRI), hepatitis C virus infection, body mass index (BMI), and diabetes. BMI was categorized as <25 kg/m^2 as underweight/normal (due to small sample size of participants with BMI <18.5 kg/m^2), 25 to <30 kg/m^2 as overweight, and ≥30 kg/m^2 as obesity, and diabetes was defined as HgbA1C ≥6.5%, fasting glucose ≥126 mg/dL, confirmed self-report diagnosis, or ever self-reported taking anti-diabetic medication[19]. Depressive symptoms were considered present if a participant scored ≥16 on the Center for Epidemiologic Studies-Depression scale (CES-D)[20], and cardiovascular disease was self-reported as history of myocardial infarction, stroke, transient ischemic attack, surgery on heart vessels, or hospitalization for congestive heart failure or angina. HIV-specific clinical risk factors included current ART use, duration of ART use in years, CD4 count, and AIDS diagnosis. Current ART was categorized as none, regimen with integrase inhibitors (INSTIs), and regimen without use of integrase inhibitors (non-INSTIs).

Statistical methods:

We described characteristics of participants by hypertension status at baseline using means and standard deviations or N (%). Kaplan-Meier plots were used to compare survival times to first awareness, treatment, and control by race/ethnicity and HIV status. We assessed time to awareness, treatment, and control using Cox proportional-hazards models for our sub-cohorts. Participants were censored if they died, were lost to follow-up, or had their 2019 visit before experiencing the hypertension event of interest. Among participants who were normotensive at baseline, we assessed time to incident hypertension and awareness, treatment, and control using Cox proportional-hazards modeling. Follow-up time for incident hypertension was time in years from baseline to diagnosis, and follow-up time for awareness, treatment, and control was time from diagnosis to the event or date of censoring. For participants who had treatment and control at the same visit as first diagnosis, three months were added to their follow-up time to be included in analyses. Because Cox models use the ordering of event times in calculating hazard ratios, we arbitrary chose three months because it falls before the six-month follow-up visit. Among participants who were hypertensive at baseline, follow-up time was calculated in years from baseline to the hypertension event of interest or censoring. Participants who were hypertensive at baseline and who were already aware, treated, and controlled were excluded from analyses. Our overall analysis included the combination of both sub-cohorts.

The crude models for calculating hazards ratios for our main comparison included only race/ethnicity. The fully adjusted model included sociodemographic, behavioral, and clinical risk factors, including HIV serostatus. The crude models for our secondary

comparison included only HIV status. The fully adjusted model added sociodemographic, behavioral, and clinical risk factors except for duration of ART, AIDS diagnosis, and ART regimen because these variables only pertained to WLWH. We assessed the proportional hazards assumption between each variable and outcome using Schoenfeld residuals. Interaction variables with log function of follow-up time were created for variables that violated the proportional hazards assumption. For the incident hypertension sub-cohort, the following variables did not meet proportional hazards assumption: education, health insurance, and duration of ART. HIV status, CD4 count, smoking status, duration of ART, and FIB-4 did not meet proportional hazards assumption for the prevalent hypertension sub-cohort. Additionally, APRI and hepatitis C virus infection were not proportional in the overall cohort.

Because results of the physical exams were communicated to the participants and efforts were made to link participants to care for conditions identified during the study visits, participation in the study may influence hypertension diagnosis, awareness, treatment, and control. Therefore, period-specific hazard ratios were conducted based on length of time enrolled: <1 year, 1 to <2.5 years, and ≥2.5 years. We examined if the hazard ratio for race/ethnicity and HIV status differed over time for each hypertension outcome using a 2-degree of freedom Wald test. Because the diagnostic criteria for hypertension changed to ≥130/80 mmHg in 2017[21], sensitivity analysis of controlled hypertension among those with high blood pressure was conducted as defined by systolic and diastolic blood pressure <130/80 mmHg. Multiple imputation with chained equations was also performed to account for missing data on covariates as a sensitivity analysis. The following covariates had missing data: health insurance, depressive symptoms,

hepatitis C, alcohol use, BMI, eGFR, FIB-4, APRI, duration of ART, and CD4 count. Analyses were performed using SAS statistical software (Cary, North Carolina), version 9.4 and statistical significance was set at α=0.05 (two-sided).

Results:

There were 845 women enrolled into the Southern sites of the WIHS, with 2 being excluded from analyses because they were previously enrolled at a non-Southern WIHS site before transferring to a Southern site (Supplemental Figure 1). Participants who reported race/ethnicity as Asian/Pacific Islander, American Indian/Alaskan, and other were excluded due to small sample size (n=15 total). Participants missing baseline systolic or diastolic blood pressure (n=3), or missing baseline covariates, were also excluded from analyses (n=113). The final sample size (n=712) included 401 participants who were hypertensive at baseline and 311 who were normotensive, of whom 45% developed incident hypertension (n=139/311).

In our sample 85% were NH Black (n=602), 10% were NH White (n=70), and 6% were Hispanic (n=40) (Table 1). There were 69% WLWH (n=493). Participants who were normotensive at baseline were younger than those with prevalent hypertension, mean age 39 years and 46 years, respectively. Participants with prevalent hypertension were more likely to be current smokers, have a higher BMI, history of CVD, and diabetes compared to participants normotensive at baseline. See Table 1 for remaining demographics and Supplemental Tables 1 and 2 for demographics of normotensive and hypertensive participants at baseline by race/ethnicity and HIV status.

The Kaplan-Meier survival plots for awareness, treatment, and control of hypertension did not show any significant differences by race/ethnicity for the overall study population (Figure 1). Follow-up time was recorded in years. No difference was seen by race/ethnicity for participants who were normotensive at baseline (Supplemental Figure 2). Among participants who were hypertensive at baseline, the survival probability for controlled hypertension (i.e., time to reach blood pressure control) was lower among Hispanic women compared to NH Black and NH White women (p=0.03) (Supplemental Figure 3).

Cox proportional hazards model for race/ethnicity, as shown in Figure 2, shows a significant difference in time to control of hypertension after adjusting for sociodemographic, behavioral, and clinical risk factors. NH White and Hispanic women had 1.82- and 1.28-times higher hazard of control compared to NH Black women (p=0.01), which means that NH White and Hispanic women controlled their hypertension more quickly (Supplemental Table 3). This remained true after fully adjusting for all covariates in the sensitivity analysis of hypertension control defined as ≤130/80 mmHg and for multiple imputation (Supplemental Table 4 and 5, respectively). Additionally, in the analysis using multiple imputation NH Black women more quickly became aware of their hypertension diagnosis compared to NH White and Hispanic women (Supplemental Table 5). See Supplemental Tables 6 and 7 for hazard ratios among participants who developed incident hypertension and who were hypertensive at baseline, respectively. Regardless of ethnicity, non-Black women also had faster time to control compared to Black women (p=0.02) (Supplemental Table 8). Period-specific hazard ratios were lower at ≥2.5 years follow-up for non-Black women compared to Black women for awareness

of hypertension. For control of hypertension, period-specific hazard ratios were higher between 1 and <2.5 years of follow-up for non-Black women compared to Black women. Additionally, the hazard ratios for race changed over time for hypertension control meaning racial disparities are more influential further from diagnosis (p=0.04, not shown) (Supplemental Figure 4).

The survival estimates between WLWH and WLWOH for awareness, treatment, or control of hypertension were similar for the overall study population (Figure 3). However, among participants who were normotensive at baseline, WLWH became aware of hypertension diagnosis and were treated for hypertension more quickly than WLWOH (p=0.03 and 0.01, respectively) (Supplemental Figure 5). See Supplemental Figure 6 for Kaplan-Meier plots of participants who were hypertensive at baseline by HIV status.

In our overall sample, WLWH had 1.42 times the hazard of hypertension control compared to WLWOH, although the confidence interval overlapped with 1 (p=0.07; Figure 4 and Supplemental Table 9). The fully adjusted model accounting for missing data with multiple imputation (Supplemental Table 10) also showed that WLWH had a faster time to control compared to WLWOH. From the sensitivity analysis, WLWH with detectable viral loads had a significantly faster time to awareness and treatment of hypertension compared to WLWOH (p=0.01); however, only a small proportion of WLWH had detectable viral load in this study population (Supplemental Table 11). Among participants who were normotensive at baseline, WLWH had faster time to treatment compared to WLWOH after adjusting for covariates (p=0.04; Supplemental Table 12). See Supplemental Table 13 for Cox proportional hazards model result for participants who were hypertensive at baseline. The sensitivity analysis of hypertension

control defined as ≤130/80 mmHg did not show significant difference (Supplemental Table 14). The hazard ratios for HIV status did not change over time for hypertension control (p=0.23, not shown) (Supplemental Figure 7).

Discussion:

In our study, we found that NH Black women more quickly became aware of their hypertension diagnosis but did not control their hypertension as quickly as NH White and Hispanic women after adjusting for sociodemographic, behavioral, and clinical factors. Cross-sectional data from NHANES from 2015-2018 showed Black women had higher awareness (70%) compared to White and Hispanic women (56% and 65%, respectively).[7] Furthermore, Black adults were more likely to be aware and treated for hypertension compared to White adults but have the highest uncontrolled hypertension rates in the US.[5,22]

From our study, we found that WLWH treated and controlled their hypertension more quickly than WLWOH, which could reflect that WLWH have better access to providers. WLWH with detectable viral loads may have also been treated more quickly than WLWOH, but few women in this study had detectable viral loads. A larger study is needed to fully understand this relationship. Our results are similar to a multicenter cohort study conducted in 2010-2014, among Italians living with HIV, which studied hypertension awareness, treatment, and control over a median of 3.4 years. The researchers noticed improvements among hypertension outcomes from baseline to end of follow-up among hypertensive participants.[23] There are few studies on the hypertension treatment cascade among PLWH in the United States. Participation in a health-focused

study, such as WIHS, that includes protocols for linkage to clinical care may lead to improved hypertension management. However, we did not find statistically significant differences in the hazard ratios for the early part of the follow-up compared to later years of study participation.

Hypertension is one of the leading risk factors for loss of disability-adjusted life years within the US.[24] Along with higher prevalence of uncontrolled hypertension, Black adults have higher prevalence of cardiovascular disease and kidney disease compared to White adults in the US.[8] The clinical implications of hypertension also extend to PLWH. Despite the advancement of combined antiretroviral therapy, HIV-related neurocognitive disorders have increased especially among WLWH.[25-27] On average, PLWH have a higher risk of dementia with a faster onset compared to persons living without HIV.[28] The risk of dementia is partially explained by cardiovascular disease, where hypertension is the leading risk factor.[28,29] With acknowledgment of these health disparities among race and HIV diagnosis, targeted interventions can help alleviate the burden of disease caused by hypertension.

This study addressed gaps in hypertension outcomes among race/ethnicity and HIV status of US women living in the South. One strength was the longitudinal data collected on participants unlike most national studies that are cross-sectional, like NHANES. We were able to determine hypertension outcomes among those with prevalent hypertension at baseline and those who later developed incident hypertension. However, this study is not without its limitations. Our results are only generalizable to WLWH within the Southern US. Self-report of key variables on questionnaires, like income and lifestyle choices, might introduce biases due to the sensitive nature of these

questions. Due to the small sample size of our cohort, we were not able to analyze results for other racial/ethnic groups besides NH Black, NH White, and Hispanic women. Furthermore, our analysis included a smaller sample size of Hispanic women compared to our other comparison groups. We defined diagnosis of hypertension and control based on average BP measurements at a single visit instead of defining hypertension and control based on consecutive visits.[30] Since the length of time of hypertension diagnosis is unknown for participants who are hypertensive at baseline, there are possible effects of left truncation in this analysis. Our analysis did not consider the number of visits to providers, which some of the lack of hypertension control and changes in medications could be related to provider inertia. Lastly, we did not collect information to determine adherence to antihypertensive medication, in which medication use was self-reported.

Few studies have prospectively looked at time to awareness, treatment, and control of hypertension among women living with or without HIV in the US. Our findings that NH Black women have faster time to awareness but slower time to controlled hypertension compared to NH White or Hispanic women generally aligned with national findings in the US.[22] By combating this disparity in healthcare, we can improve management of hypertension in vulnerable populations. Our study has also shown that WLWH have faster time to treatment and control of hypertension compared to WLWOH suggests that the enhanced healthcare contact and access associated with an HIV diagnosis and participation in clinical research studies may improve overall health outcomes.

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Table 1. Characteristics of study population for women enrolled at Southern sites of the Women's Interagency HIV Study (N=712)

	Overall (N=712)	Hypertensive at baseline (n=401)	Normotensive at baseline (n=311)
Baseline age, y	43.2 ± 9.4	46.2 ± 9.0	39.4 ± 8.5
Race/ethnicity			
NH Black	602 (84.6)	361 (90.0)	241 (77.5)
NH White	70 (9.8)	30 (7.5)	40 (12.9)
Hispanic	40 (5.6)	10 (2.5)	30 (9.7)
Education			
Less than high school	214 (30.1)	121 (30.2)	93 (29.9)
High school graduate	222 (31.2)	123 (30.7)	99 (31.8)
Some college	226 (31.7)	125 (31.2)	101 (32.5)
College graduate or higher	50 (7.0)	32 (8.0)	18 (5.8)
Health insurance			
Uninsured	166 (23.3)	94 (23.4)	72 (23.2)
Medicaid only	261 (36.7)	88 (22.0)	119 (38.3)
ADAP only	107 (15.0)	52 (13.0)	55 (17.7)
Other[a]	178 (25.0)	167 (41.7)	65 (20.9)
Smoking status			
Never	289 (40.6)	148 (36.9)	141 (45.3)
Former	93 (13.1)	61 (15.2)	32 (10.3)
Current	330 (46.4)	192 (47.9)	138 (44.4)
Alcohol use,[b] %			
None	336 (47.2)	191 (47.6)	145 (46.6)
Moderate	251 (35.3)	135 (33.7)	116 (37.3)
Heavy	125 (17.6)	75 (18.7)	50 (16.1)
Substance use			
None	233 (32.7)	119 (29.7)	114 (36.7)
Marijuana only	117 (16.4)	54 (13.5)	63 (20.3)
Nonintravenous drug use	316 (44.4)	199 (49.6)	117 (37.6)
Intravenous drug use	46 (6.5)	29 (7.2)	17 (5.5)
Body mass index,[c] %			
Underweight/Normal	123 (17.3)	57 (14.2)	66 (21.2)
Overweight	163 (22.9)	73 (18.2)	90 (28.9)
Obesity	426 (59.8)	271 (67.6)	155 (49.8)
History of CVD,[d] %	64 (9.0)	50 (12.5)	14 (4.5)
Diabetes,[e] %	84 (11.8)	72 (18.0)	12 (3.9)
eGFR	100.8 ± 23.7	97.9 ± 25.5	104.5 ± 20.7
Hepatic fibrosis	1.06 ± 1.0	1.13 ± 1.1	0.97 ± 0.6
APRI	0.3 ± 0.4	0.3 ± 0.5	0.3 ± 0.2
Hepatitis C	84 (11.8)	59 (14.7)	25 (8.0)
Depressive symptoms[f]	327 (45.9)	191 (47.6)	136 (43.7)

HIV status			
Negative	219 (30.8)	115 (30.1)	104 (34.3)
Suppressed[g]	363 (51.0)	197 (51.6)	151 (48.6)
Unsuppressed	130 (18.3)	70 (18.3)	56 (18.0)
Current ART usage			
None	28 (5.7)	13 (4.6)	15 (7.25)
INSTIs	162 (32.9)	92 (32.2)	70 (33.8)
Non-INSTIs	303 (61.5)	181 (63.3)	122 (58.9)
Duration of ART, y	4.1 ± 2.7	4.1 ± 2.7	3.9 ±2.7±
CD4 count, cells/μL	752.5 ± 414.6	751.5 ± 419.8	753.9 ± 408.4
AIDS diagnosis	54 (7.6)	33 (11.5)	21 (10.1)

Data are presented as mean ± SD or No. (%).

Abbreviations: ADAP, AIDS Drug Assistance Program; APRI, aspartate aminotransferase/platelet ratio; ART, antiretroviral therapy; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; INSTI, integrase inhibitor; NH, non-Hispanic; WLWH, women living with HIV; WLWOH, women living without HIV.

[a]Other includes private, Medicare, combination of insurances, and other insurance.

[b]Rank based on none, moderate (1-7 drinks/wk), and heavy (>7 drinks/wk) according to National Institute on Alcohol Abuse and Alcoholism guidelines for women.

[c]Body mass index (kg/m^2) defined as underweight/normal (<25), overweight (25 to <30), and obesity (≥30).

[d]History of CVD includes, myocardial infarction, hospitalization for congestive heart failure, stroke, transient ischemic attack, hospitalization for angina, or surgery on heart vessels.

[e]Diabetes defined as fasting glucose ≥126 mg/dL, hemoglobin A_{1C} ≥6.5%, confirmed self-report diagnosis, or ever self-reported anti-diabetic medication.

[f]Depressive symptoms defined Center for Epidemiologic Studies-Depression score ≥16.

[g]Cutoff for viral suppression was <20 copies/mL.

Figure 1. Survival estimates of hypertension outcomes by race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study (N=712)

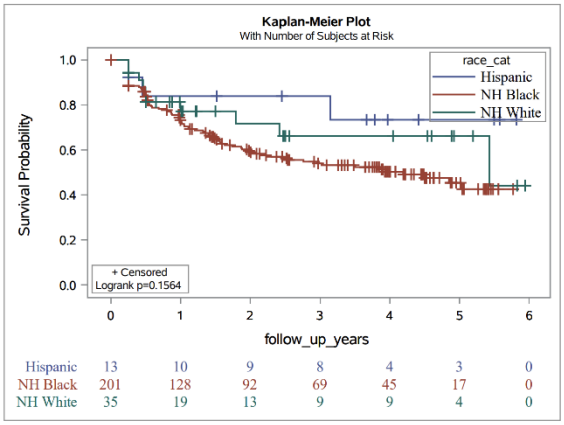


Figure A. Awareness

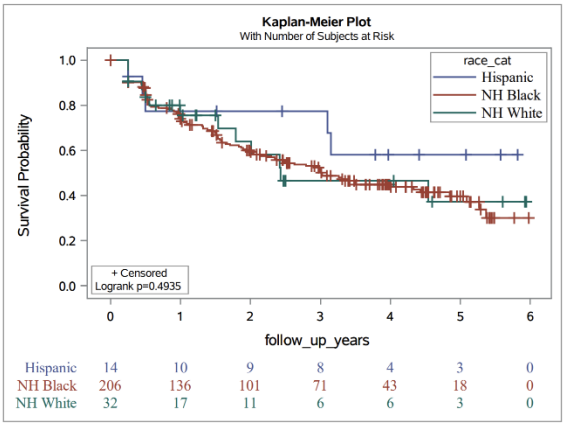


Figure B. Treatment

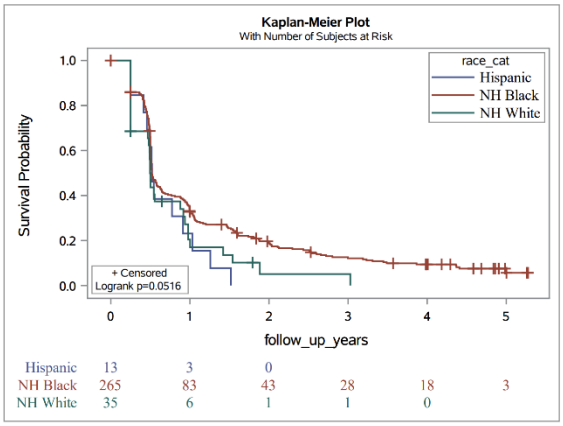
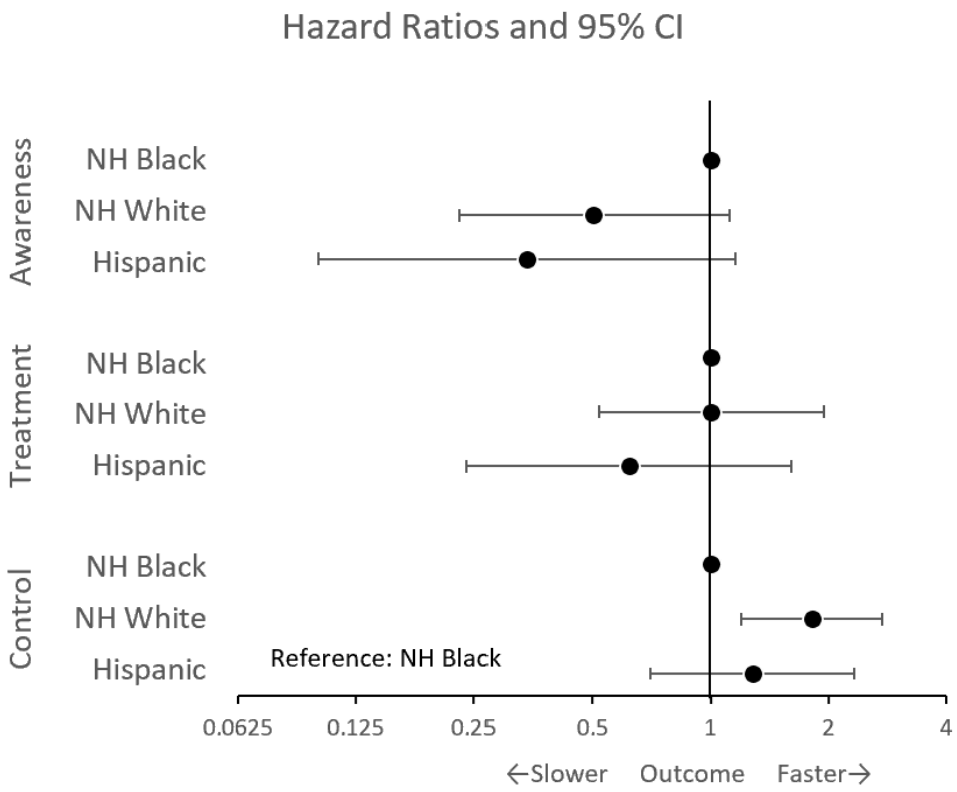


Figure C. Control

Abbreviation: NH, non-Hispanic

Figure 2. Adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study



Abbreviation: NH, non-Hispanic.

X-axis shown on logarithmic scale.

Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Figure 3. Survival estimates of hypertension outcomes by HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study (N=712)

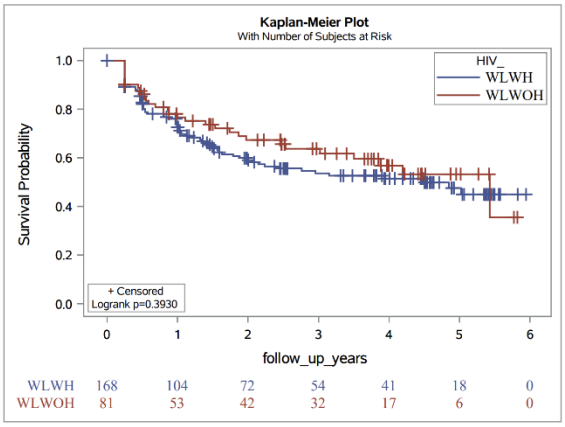


Figure A. Awareness

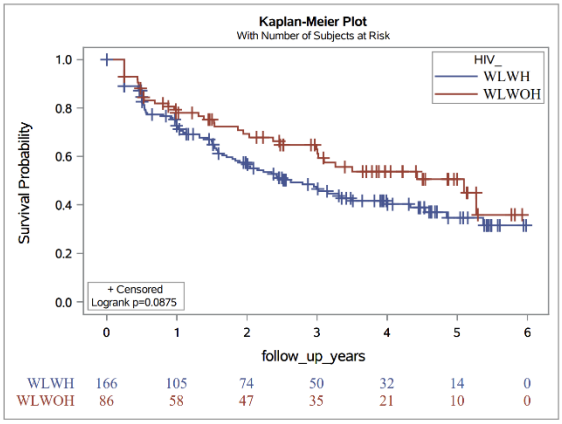


Figure B. Treatment

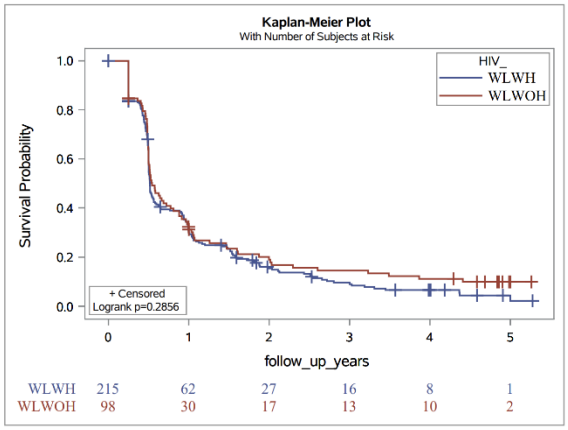
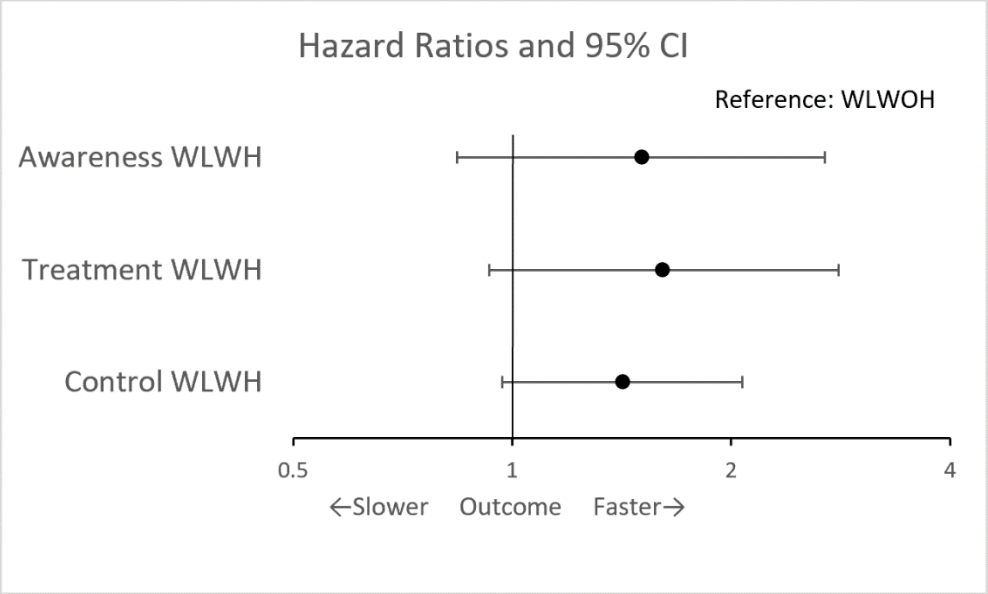


Figure C. Control

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV

Figure 4. Adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study



Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV. X-axis shown on logarithmic scale.

Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, and HIV.

Table S1. Characteristics of study population for women enrolled at Southern sites of the Women's Interagency HIV Study who were normotensive at baseline (n=311)

	NH Black (n=241)	NH White (n=40)	Hispanic (n=30)	*P* value	WLWOH (n=104)	WLWH (n=207)	*P* value
Baseline age, y	39.3 ± 8.6	40.4 ± 8.8	39.1 ± 8.3	0.72	38.4 ± 8.2	39.9 ± 8.7	0.16
Race/ethnicity	---	---	---	---			0.84
NH Black					79 (76.0)	162 (78.3)	
NH White					15 (14.4)	25 (12.1)	
Hispanic					10 (9.6)	20 (9.7)	
Education				0.14			0.05
Less than high school	73 (30.3)	7 (17.5)	13 (43.3)		30 (28.9)	63 (30.4)	
High school graduate	72 (29.9)	16 (40.0)	11 (36.7)		24 (23.1)	75 (36.2)	
Some college	80 (33.2)	16 (40.0)	5 (16.7)		43 (41.4)	58 (28.0)	
College graduate or higher	16 (6.6)	1 (2.5)	1 (3.3)		7 (6.7)	11 (5.3)	
Health insurance				**0.02**			**<0.001**
Uninsured	51 (21.2)	11 (27.5)	10 (33.3)		45 (43.3)	27 (13.0)	
Medicaid only	75 (31.1)	6 (15.0)	7 (23.3)		31 (29.8)	57 (27.5)	
ADAP only	38 (15.8)	7 (17.5)	10 (33.3)		0 (0.0)	55 (26.6)	
Other[a]	77 (32.0)	16 (40.0)	3 (10.0)		28 (26.9)	68 (32.9)	
Smoking status				0.05[b]			0.05
Never	114 (47.3)	10 (25.0)	17 (56.7)		38 (36.5)	103 (49.8)	
Former	23 (9.5)	6 (15.0)	3 (10.0)		10 (9.6)	22 (10.6)	
Current	104 (43.2)	24 (60.0)	10 (33.3)		56 (53.9)	82 (39.6)	
Alcohol use,[c] %				0.59			**0.005**
None	110 (45.6)	18 (45.0)	17 (56.7)		37 (35.6)	108 (52.2)	
Moderate	94 (39.0)	13 (32.5)	9 (30.0)		42 (40.4)	74 (35.8)	
Heavy	37 (15.4)	9 (22.5)	4 (13.3)		25 (24.0)	25 (10.1)	
Substance use				0.33[b]			0.34[b]
None	172 (71.4)	28 (70.0)	22 (73.3)		72 (69.2)	150 (72.5)	
Marijuana only	34 (14.1)	3 (7.5)	3 (10.0)		18 (17.3)	22 (10.6)	
Nonintravenous drug use	34 (14.1)	8 (20.0)	4 (13.3)		13 (12.5)	33 (15.9)	
Intravenous drug use	1 (0.4)	1 (2.5)	1 (3.3)		1 (1.0)	2 (1.0)	
Body mass index,[d] %				0.09			0.33
Underweight/ Normal	44 (18.3)	13 (32.5)	9 (30.0)		20 (19.2)	46 (22.2)	
Overweight	69 (28.6)	10 (25.0)	11 (36.7)		26 (25.0)	64 (30.9)	
Obesity	128 (53.1)	17 (42.5)	10 (33.3)		58 (55.8)	97 (46.9)	
History of CVD,[e] %	11 (4.6)	3 (7.5)	0 (0.0)	0.38[b]	5 (4.8)	9 (4.4)	0.85
Diabetes,[f] %	11 (4.6)	1 (2.5)	0 (0.0)	0.76[b]	2 (1.9)	10 (4.8)	0.35[b]
eGFR	106.7 ± 20.2	90.4 ± 22.6	105.7 ± 14.4	**<0.001**	108.7 ± 19.0	102.5 ± 21.2	**0.01**
Hepatic fibrosis	1.0 ± 0.6	1.0 ± 0.6	1.0 ± 0.7	0.75	0.8 ± 0.5	1.0 ± 0.7	**0.006**
APRI	0.2 ± 0.2	0.3 ± 0.3	0.3 ± 0.2	0.11	0.2 ± 0.2	0.3 ± 0.2	**0.003**
Hepatitis C	12 (5.0)	10 (25.0)	3 (10.0)	**0.004[b]**	7 (6.7)	18 (8.7)	0.55
Depressive symptoms[g]	100 (41.5)	21 (52.5)	15 (50.0)	0.33	47 (45.2)	89 (43.0)	0.71

HIV status Negative Suppressed[h] Unsuppressed	 79 (33.6) 119 (50.6) 37 (15.7)	 15 (38.5) 17 (43.6) 7 (18.0)	 10 (34.5) 10 (34.5) 9 (31.0)	0.26	---	---	---
Current ART usage None INSTIs Non-INSTIs	 12 (7.4) 50 (30.9) 100 (61.7)	 2 (8.0) 12 (48.0) 11 (44.0)	 1 (5.0) 8 (40.0) 11 (55.0)	0.44[b]	 --- 	 15 (7.3) 70 (33.8) 122 (58.9)	---
Duration of ART, y	4.0 ± 2.7	3.6 ± 2.6	4.2 ± 2.7	0.76	---	3.9 ± 2.7	---
CD4 count, cells/μL	748.0 ± 400.5	831.5 ± 425.3	697.7 ± 447.2	0.36	1090.9 ± 380.9	584.6 ± 303.7	**<0.001**
AIDS diagnosis	15 (9.3)	2 (8.0)	4 (20.0)	0.32[b]	---	21 (10.1)	---

Data are presented as mean ± SD or No. (%).

Abbreviations: ADAP, AIDS Drug Assistance Program; APRI, aspartate aminotransferase/platelet ratio; ART, antiretroviral therapy; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; INSTI, integrase inhibitor; NH, non-Hispanic; WLWH, women living with HIV; WLWOH, women living without HIV.

[a]Other includes private, Medicare, combination of insurances, and other insurance.

[b]Fisher's exact test. Bold type indicates significance.

[c]Rank based on none, moderate (1-7 drinks/wk), and heavy (>7 drinks/wk) according to National Institute on Alcohol Abuse and Alcoholism guidelines for women.

[d]Body mass index (kg/m^2) defined as underweight/normal (<25), overweight (25 to <30), and obesity (≥30).

[e]History of CVD includes, myocardial infarction, hospitalization for congestive heart failure, stroke, transient ischemic attack, hospitalization for angina, or surgery on heart vessels.

[f]Diabetes defined as fasting glucose ≥126 mg/dL, hemoglobin A_{1C} ≥6.5%, confirmed self-report diagnosis, or ever self-reported anti-diabetic medication.

[g]Depressive symptoms defined Center for Epidemiologic Studies-Depression score ≥16.

[h]Cutoff for viral suppression was <20 copies/mL.

Table S2. Characteristics of study population for women enrolled at Southern sites of the Women's Interagency HIV Study who were hypertensive at baseline (n=401)

	NH Black (n=361)	NH White (n=30)	Hispanic (n=10)	*P* value[a]	WLWOH (n=115)	WLWH (n=286)	*P* value
Baseline age, y	46.0 ± 9.1	48.8 ± 7.2	45.8 ± 9.8	0.27	45.2 ± 9.8	46.6 ± 8.6	0.15
Race/ethnicity	---	---	---	---			0.55
NH Black					106 (92.2)	255 (89.2)	
NH White					6 (5.2)	24 (8.4)	
Hispanic					3 (2.6)	7 (2.5)	
Education				0.46			0.88
Less than high school	108 (29.9)	10 (33.3)	3 (30.0)		36 (31.3)	85 (29.7)	
High school graduate	107 (29.6)	10 (33.3)	6 (60.0)		32 (27.8)	91 (31.8)	
Some college	117 (32.4)	7 (23.3)	1 (10.0)		38 (33.0)	87 (30.4)	
College graduate or higher	29 (8.0)	3 (10.0)	0 (0.0)		9 (7.8)	23 (8.0)	
Health insurance				0.46			**<0.001**
Uninsured	81 (22.4)	9 (30.0)	4 (40.0)		58 (50.4)	36 (12.6)	
Medicaid only	83 (23.0)	5 (16.7)	0 (0.0)		24 (20.9)	64 (22.4)	
ADAP only	46 (12.7)	4 (13.3)	2 (20.0)		0 (0.0)	52 (18.2)	
Other[b]	151 (41.8)	12 (40.0)	4 (40.0)		33 (28.7)	134 (46.9)	
Smoking status				0.19			**0.008**
Never	136 (37.7)	7 (23.3)	5 (50.0)		34 (29.6)	114 (39.9)	
Former	53 (14.7)	8 (26.7)	0 (0.0)		12 (10.4)	49 (17.1)	
Current	172 (47.7)	15 (50.0)	5 (50.0)		69 (60.0)	123 (43.0)	
Alcohol use,[c] %				0.52			**0.002**
None	168 (46.5)	16 (53.3)	7 (70.0)		54 (47.0)	137 (47.9)	
Moderate	125 (34.6)	9 (30.0)	1 (10.0)		28 (24.4)	107 (37.4)	
Heavy	68 (18.8)	5 (16.7)	2 (20.0)		33 (28.7)	42 (14.7)	
Substance use				0.22			**<0.001[a]**
None	244 (67.6)	18 (60.0)	7 (70.0)		68 (59.1)	201 (70.3)	
Marijuana only	55 (15.2)	6 (20.0)	2 (20.0)		13 (11.3)	50 (17.5)	
Nonintravenous drug use	62 (17.2)	5 (16.7)	1 (10.0)		33 (28.7)	35 (12.2)	
Intravenous drug use	0 (0.0)	1 (3.3)	0 (0.0)		1 (0.9)	0 (0.0)	
Body mass index,[d] %				0.21			0.18
Underweight/ Normal	51 (14.1)	5 (16.7)	1 (10.0)		15 (13.0)	42 (14.7)	
Overweight	61 (16.9)	8 (26.7)	4 (40.0)		15 (13.0)	58 (20.3)	
Obesity	249 (69.0)	17 (56.7)	5 (50.0)		85 (73.9)	186 (65.0)	
History of CVD,[e] %	45 (12.5)	2 (6.7)	3 (30.0)	0.13	18 (15.7)	32 (11.2)	0.22
Diabetes,[f] %	65 (18.0)	4 (13.3)	3 (30.0)	0.46	26 (22.6)	46 (16.1)	0.12
eGFR	99.3 ± 25.5	81.1 ± 20.8	96.3 ± 22.0	**0.001**	103.7 ± 22.7	95.6 ± 26.2	**0.004**
Hepatic fibrosis	1.1 ± 1.2	1.3 ± 0.9	1.0 ± 0.4	0.73	1.1 ± 1.5	1.1 ± 0.9	0.84
APRI	0.3 ± 0.5	0.4 ± 0.6	0.3 ± 0.2	0.62	0.3 ± 0.8	0.3 ± 0.3	0.69
Hepatitis C	50 (13.9)	9 (30.0)	0 (0.0)	**0.03**	21 (18.3)	38 (13.3)	0.20
Depressive symptoms[g]	172 (47.7)	16 (53.3)	3 (30.0)	0.47	63 (54.8)	128 (44.8)	0.07

HIV status Negative Suppressed[h] Unsuppressed	 106 (30.6) 176 (50.7) 65 (18.7)	 6 (23.1) 17 (65.4) 3 (11.5)	 3 (33.3) 4 (44.4) 2 (22.2)	0.69	---	---	---
Current ART usage None INSTIs Non-INSTIs	 13 (5.1) 80 (31.4) 162 (63.5)	 0 (0.0) 10 (41.7) 14 (58.3)	 0 (0.0) 2 (28.6) 5 (71.4)	0.78	---	 13 (4.6) 92 (32.2) 181 (63.3)	---
Duration of ART, y	4.2 ± 2.7	3.6 ± 2.3	4.6 ± 4.2	0.59	---	4.1 ± 2.7	---
CD4 count, cells/μL	745.1 ±409.6	840.1 ± 515.9	716.1 ± 486.1	0.48	1092.2 ± 426.1	614.4 ± 330.2	**<0.001**
AIDS diagnosis	28 (11.0)	4 (16.7)	1 (14.3)	0.52	---	33 (11.5)	---

Data are presented as mean ± SD or No. (%).

Abbreviations: ADAP, AIDS Drug Assistance Program; APRI, aspartate aminotransferase/platelet ratio; ART, antiretroviral therapy; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; INSTI, integrase inhibitor; NH, non-Hispanic; WLWH, women living with HIV; WLWOH, women living without HIV.

[a]Fisher's exact test.

[b]Other includes private, Medicare, combination of insurances, and other insurance.

[c]Rank based on none, moderate (1-7 drinks/wk), and heavy (>7 drinks/wk) according to National Institute on Alcohol Abuse and Alcoholism guidelines for women.

[d]Body mass index (kg/m^2) defined as underweight/normal (<25), overweight (25 to <30), and obesity (≥30).

[e]History of CVD includes, myocardial infarction, hospitalization for congestive heart failure, stroke, transient ischemic attack, hospitalization for angina, or surgery on heart vessels.

[f]Diabetes defined as fasting glucose ≥126 mg/dL, hemoglobin A_{1C} ≥6.5%, confirmed self-report diagnosis, or ever self-reported anti-diabetic medication.

[g]Depressive symptoms defined Center for Epidemiologic Studies-Depression score ≥16.

[h]Cutoff for viral suppression was <20 copies/mL.

Table S3. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Awareness (n=249)		0.12		0.07
NH Black	1 [Reference]		1 [Reference]	
NH White	0.64 (.34–1.24)		0.50 (.23–1.12)	
Hispanic	0.38 (.12–1.19)		0.34 (.10–1.16)	
Treatment (n=252)		0.48		0.61
NH Black	1 [Reference]		1 [Reference]	
NH White	0.88 (.49–1.56)		1.00 (.52–1.95)	
Hispanic	0.62 (.27–1.40)		0.62 (.24–1.61)	
Control (n=313)		0.06		**0.01**
NH Black	1 [Reference]		1 [Reference]	
NH White	1.50 (1.03–2.17)		1.82 (1.20–2.75)	
Hispanic	1.43 (.84–2.41)		1.28 (.70–2.33)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S4. Unadjusted and adjusted hazard ratios and 95% CIs for the association between control of hypertension (≤130/80 mmHg) and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Control (n=403)		**0.01**		**0.02**
NH Black	1 [Reference]		1 [Reference]	
NH White	1.44 (1.01–2.04)		1.46 (.99–2.16)	
Hispanic	1.82 (1.10–3.03)		1.98 (1.10–3.58)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S5. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study using multiple imputation

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Awareness (n=294)		0.15		**0.02**
NH Black	1 [Reference]		1 [Reference]	
NH White	0.57 (.30–1.09)		0.39 (.18–.85)	
Hispanic	0.63 (.28–1.44)		0.47 (.19–1.14)	
Treatment (n=305)		0.62		0.62
NH Black	1 [Reference]		1 [Reference]	
NH White	0.85 (.49–1.48)		0.82 (.44–1.52)	
Hispanic	0.75 (.38–1.48)		0.74 (.35–1.53)	
Control (n=372)		**0.02**		**0.02**
NH Black	1 [Reference]		1 [Reference]	
NH White	1.48 (1.04–2.10)		1.56 (1.06–2.29)	
Hispanic	1.61 (1.03–2.53)		1.60 (.99–2.59)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S6. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study who were normotensive at baseline

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Incident hypertension (n=311)		0.13		0.46
NH Black	1 [Reference]		1 [Reference]	
NH White	1.35 (.86–2.11)		1.12 (.65–1.92)	
Hispanic	0.63 (.33–1.20)		0.67 (.32–1.37)	
Awareness (n=139)		0.08		0.09
NH Black	1 [Reference]		1 [Reference]	
NH White	0.33 (.10–1.06)		0.21 (.04–1.02)	
Hispanic	0.39 (.09–1.61)		0.42 (.07–2.60)	
Treatment (n=139)		0.64		0.88
NH Black	1 [Reference]		1 [Reference]	
NH White	0.73 (.31–1.71)		0.84 (.28–2.52)	
Hispanic	0.67 (.21–2.17)		1.32 (.34–5.04)	
Control (n=139)		0.30		0.30
NH Black	1 [Reference]		1 [Reference]	
NH White	1.17 (.72–1.90)		0.88 (.44–1.74)	
Hispanic	0.64 (.33–1.24)		0.55 (.25–1.20)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S7. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study who were hypertensive at baseline

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Awareness (n=110)		0.60		0.48
NH Black	1 [Reference]		1 [Reference]	
NH White	1.14 (.51–2.53)		1.10 (.40–3.05)	
Hispanic	0.39 (.05–2.84)		0.26 (.03–2.66)	
Treatment (n=113)		0.59		0.25
NH Black	1 [Reference]		1 [Reference]	
NH White	1.17 (.54–2.55)		1.82 (.68–4.91)	
Hispanic	0.58 (.18–1.84)		0.45 (.08–2.44)	
Control (n=174)		**0.03**		0.09
NH Black	1 [Reference]		1 [Reference]	
NH White	1.34 (.74–2.43)		1.61 (.80–3.22)	
Hispanic	3.15 (1.27–7.80)		2.83 (.89–9.05)	

Abbreviation: NH, non-Hispanic.

[a]Race/ethnicity only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S8. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and race for women enrolled at Southern sites of the Women's Interagency HIV Study

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value	Model 2[b]	*P* value
Awareness (n=286)		0.08		0.08
Black	1 [Reference]		1 [Reference]	
Non-Black	0.68 (.44–1.05)		0.63 (.38–1.06)	
Treatment (n=276)		0.39		0.79
Black	1 [Reference]		1 [Reference]	
Non-Black	0.85 (.58–1.24)		0.94 (.60–1.47)	
Control (n=335)		0.06		**0.02**
Black	1 [Reference]		1 [Reference]	
Non-Black	1.28 (.99–1.66)		1.40 (1.05–1.86)	

Bold type indicates significance.

[a]Race only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Table S9. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value	Model 2[b]	*P* value
Awareness (n=249)		0.49		0.17
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.16 (.77–1.74)		1.51 (.84–2.69)	
Treatment (n=252)		0.08		0.09
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.40 (.97–2.04)		1.61 (.93–2.81)	
Control (n=313)		0.16		0.07
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.20 (.93–1.53)		1.42 (.97–2.07)	

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Table S10. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study using multiple imputation

Hazard ratio (95% CI)				
	Model 1[a]	*P* value	Model 2[b]	*P* value
Awareness (n=294)		0.44		0.23
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.17 (.78–1.75)		1.40 (.81–2.44)	
Treatment (n=305)		0.10		0.08
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.36 (.94–1.96)		1.60 (.95–2.69)	
Control (n=372)		0.13		**0.04**
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.21 (.95–1.54)		1.45 (1.02–2.05)	

Bold type indicates significance.

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Table S11. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and HIV viral load for women enrolled at Southern sites of the Women's Interagency HIV Study

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value[b]	Model 2[c]	*P* value[b]
Awareness (n=261)		0.10		**0.007**
WLWOH	1 [Reference]		1 [Reference]	
WLWH, suppressed	1.02 (.66–1.57)		1.29 (.71–2.33)	
WLWH, unsuppressed	1.68 (.98–2.86)		3.03 (1.43–6.42)	
Treatment (n=269)		**0.001**		**0.01**
WLWOH	1 [Reference]		1 [Reference]	
WLWH, suppressed	1.13 (.76–1.70)		1.34 (.75–2.39)	
WLWH, unsuppressed	2.29 (1.45–3.61)		2.46 (1.29–4.71)	
Control (n=328)		0.23		0.08
WLWOH	1 [Reference]		1 [Reference]	
WLWH, suppressed	1.25 (.96–1.63)		1.52 (1.03–2.25)	
WLWH, unsuppressed	1.08 (.77–1.50)		1.19 (.75–1.88)	

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV suppression status only (unadjusted).

[b]Type 3 significant *P* value indicated that at least 1 group is different from another. Bold type indicates significance.

[c]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Table S12. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study who were normotensive at baseline

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value	Model 2[b]	*P* value
Incident hypertension (n=311)		0.95		0.84
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.01 (.71–1.43)		1.05 (.66–1.67)	
Awareness (n=139)		**0.03**		0.09
WLWOH	1 [Reference]		1 [Reference]	
WLWH	2.14 (1.07–4.29)		2.64 (.87–7.99)	
Treatment (n=139)		**0.01**		**0.04**
WLWOH	1 [Reference]		1 [Reference]	
WLWH	2.40 (1.20–4.77)		3.33 (1.02–10.94)	
Control (n=139)		0.88		0.38
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.03 (.72–1.48)		1.33 (.71–2.51)	

Bold type indicates significance.

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Table S13. Unadjusted and adjusted hazard ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study who were hypertensive at baseline

	Hazard ratio (95% CI)			
	Model 1[a]	*P* value	Model 2[b]	*P* value
Awareness (n=110)		0.21		0.11
WLWOH	1 [Reference]		1 [Reference]	
WLWH	0.72 (.42–1.21)		0.49 (.20–1.19)	
Treatment (n=113)		0.76		0.86
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.07 (.68–1.70)		0.94 (.44–2.00)	
Control (n=174)		0.08		0.10
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.36 (.96–1.93)		1.58 (.92–2.70)	

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Table S14. Unadjusted and adjusted hazard ratios and 95% CIs for the association between control of hypertension (≤130/80 mmHg) and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study

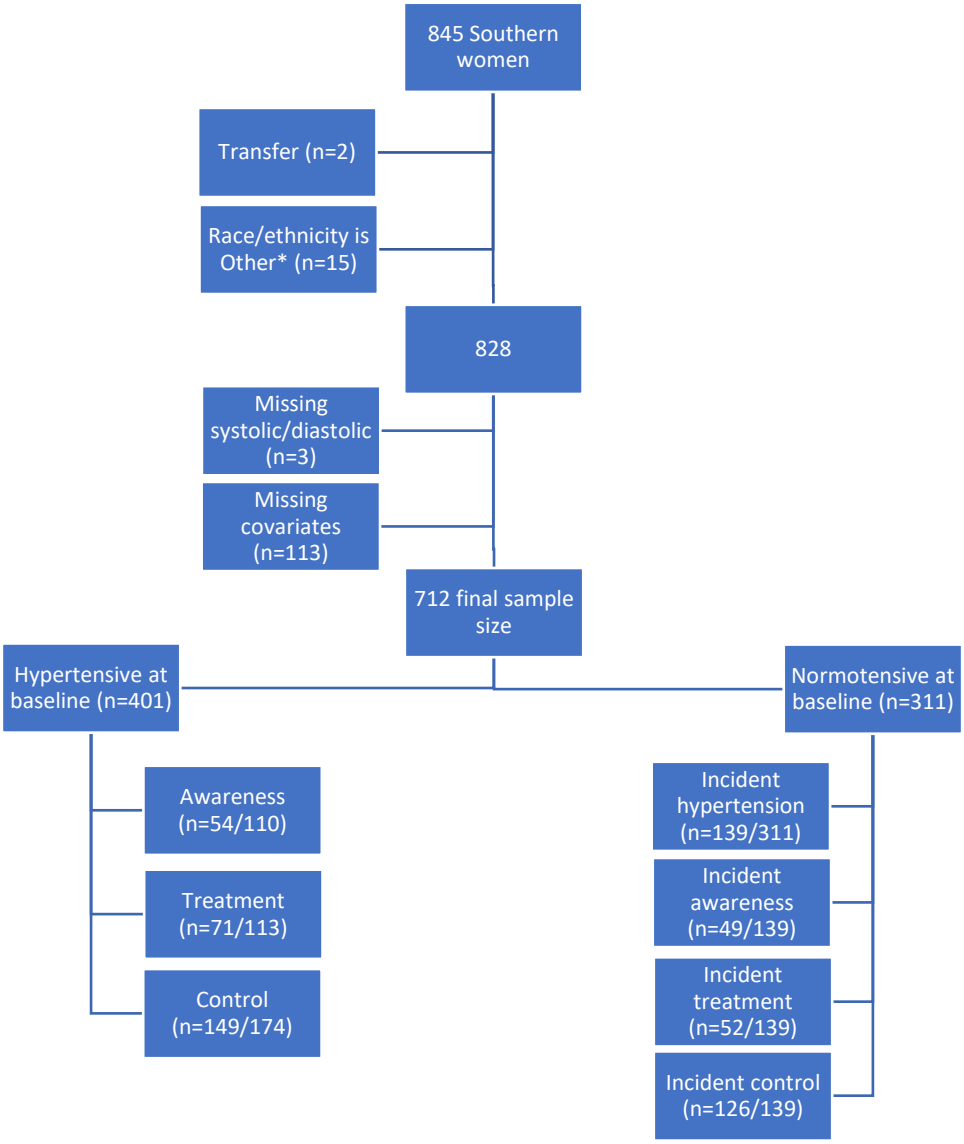
	Hazard ratio (95% CI)			
	Model 1[a]	*P* value	Model 2[b]	*P* value
Control (n=403)		0.94		0.25
WLWOH	1 [Reference]		1 [Reference]	
WLWH	1.01 (.80–1.28)		1.22 (.87–1.73)	

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV.

[a]HIV status only (unadjusted).

[b]Model 1 + all covariates (fully adjusted). Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

Figure S1. Flowchart of exclusion criteria for women enrolled at Southern sites of the Women's Interagency HIV Study



* Other includes Asian/Pacific Islander, American Indian/Alaskan, and other

Figure S2. Survival estimates of hypertension outcomes by race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study who were normotensive at baseline (n=311)

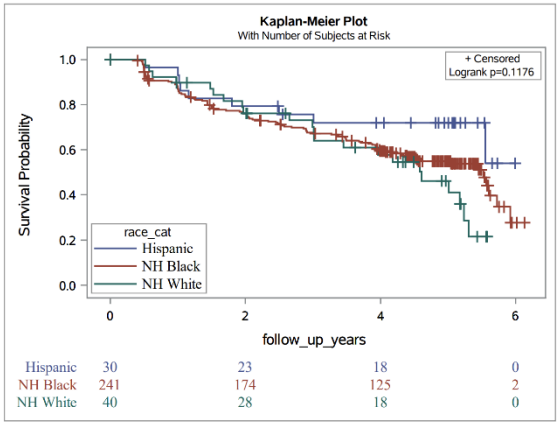


Figure A. Incident hypertension

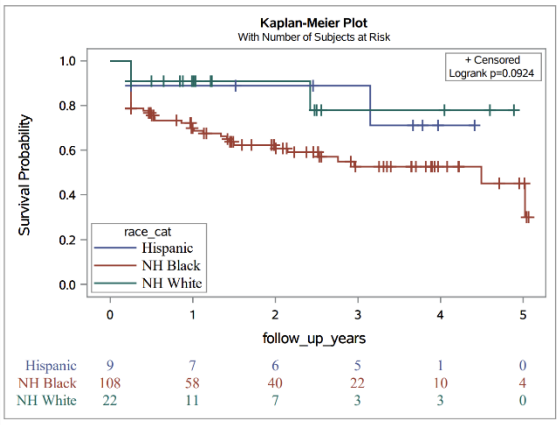


Figure B. Awareness

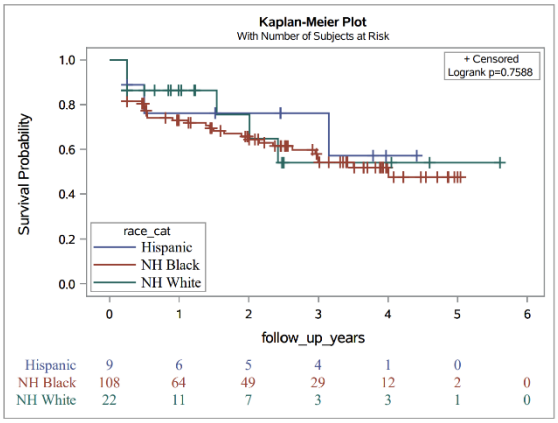


Figure C. Treatment

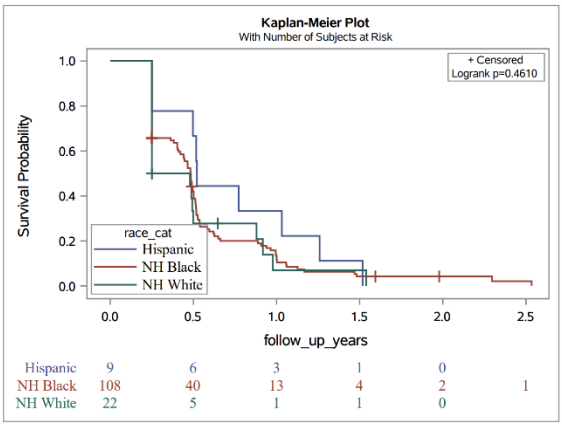


Figure D. Control

Abbreviation: NH, non-Hispanic

Figure S3. Survival estimates of hypertension outcomes by race/ethnicity for women enrolled at Southern sites of the Women's Interagency HIV Study who were hypertensive at baseline (n=401)

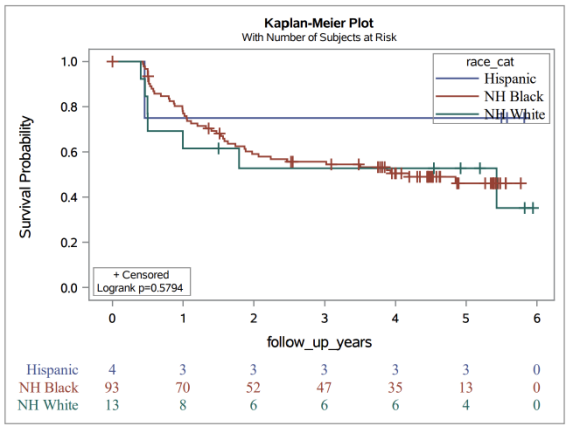


Figure A. Awareness

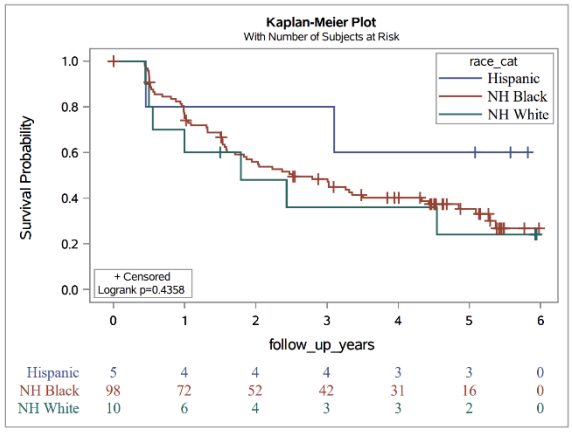


Figure B. Treatment

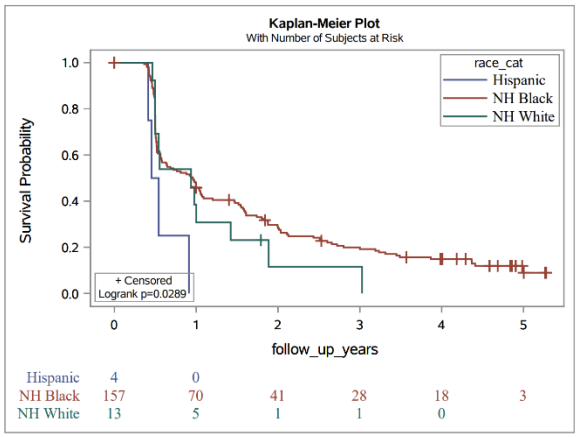
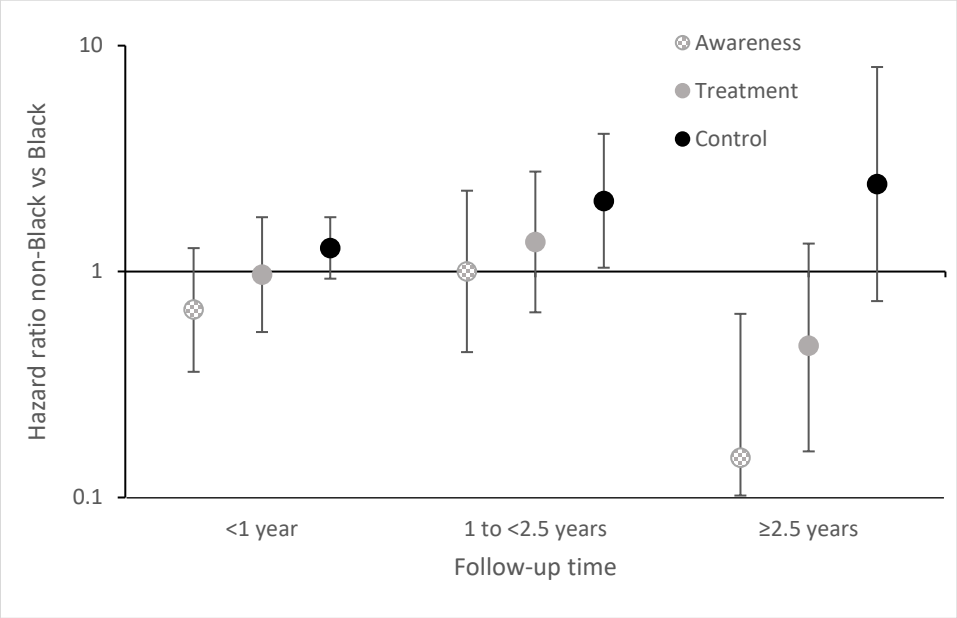


Figure C. Control

Abbreviation: NH, non-Hispanic

Figure S4. Adjusted period-specific hazard ratios and 95% CIs for the association between hypertension outcomes and race for women enrolled at Southern sites of the Women's Interagency HIV Study



Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, CD4 count, HIV, and interactions between HIV and antiretroviral therapy, duration of antiretroviral therapy, and AIDS.

Figure S5. Survival estimates of hypertension outcomes by HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study who were normotensive at baseline (n=311)

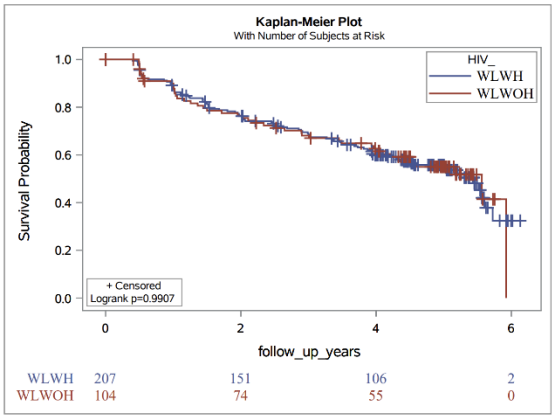


Figure A. Incident hypertension

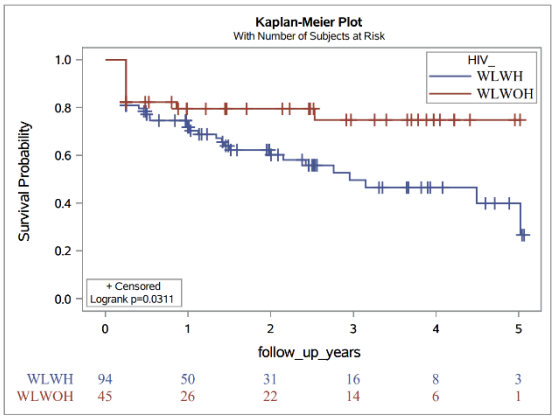


Figure B. Awareness

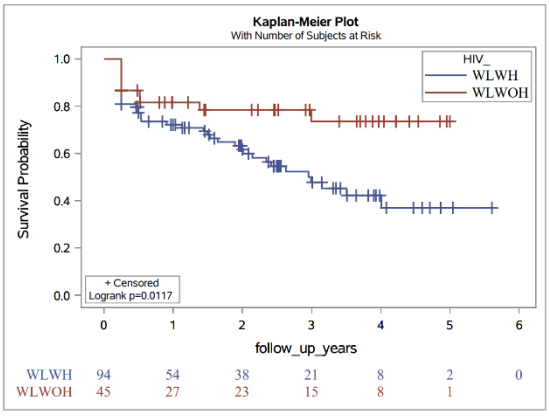


Figure C. Treatment

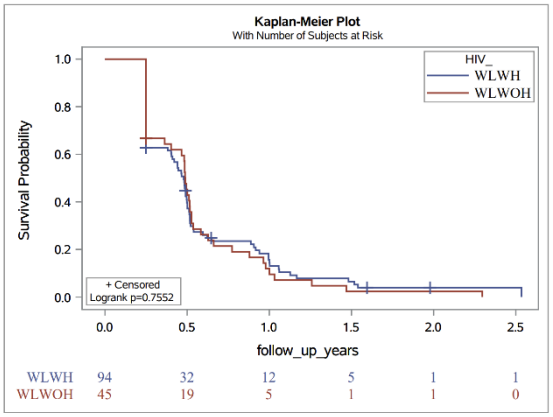


Figure D. Control

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV

Figure S6. Survival estimates of hypertension outcomes by HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study who were hypertensive at baseline (n=401)

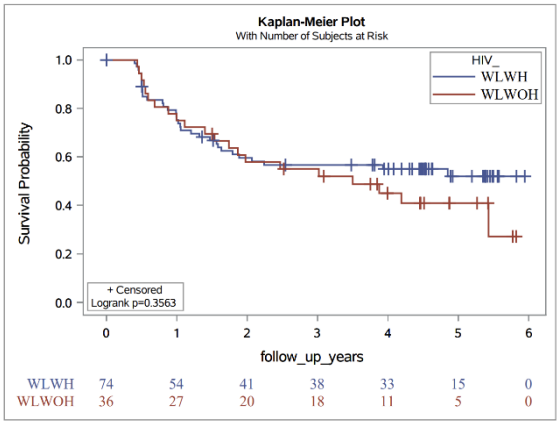


Figure A. Awareness

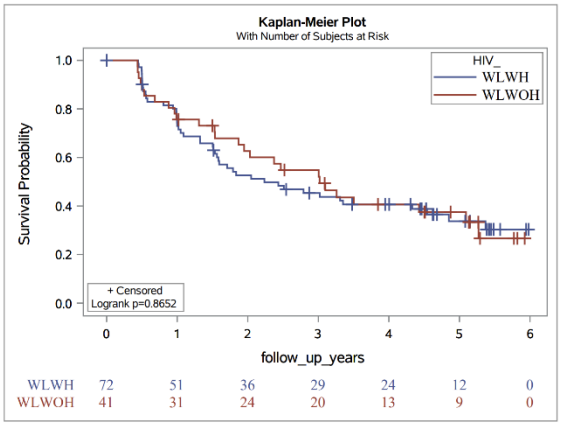


Figure B. Treatment

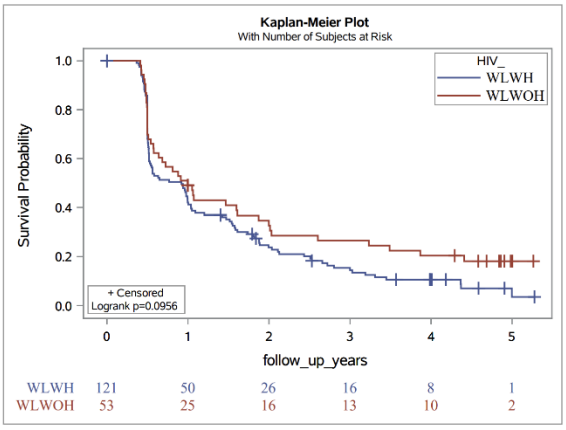
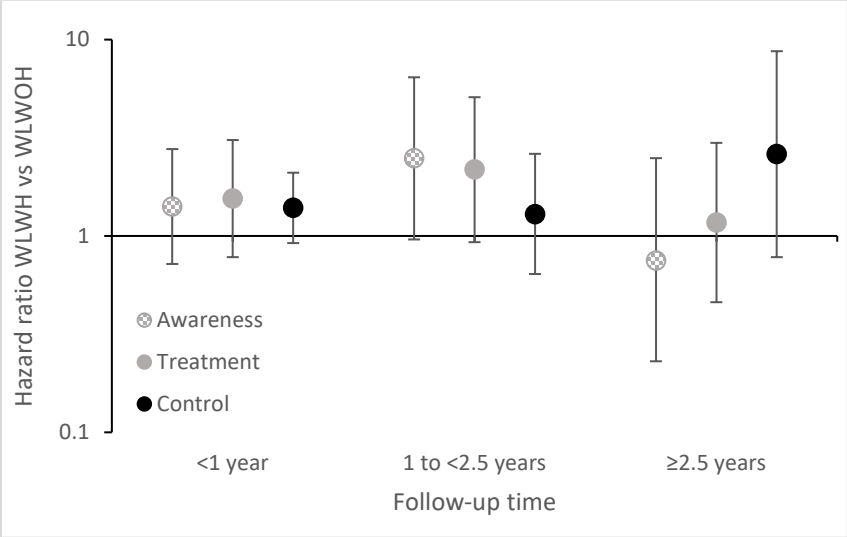


Figure C. Control

Abbreviation: WLWH, women living with HIV; WLWOH, women living without HIV

Figure S7. Adjusted period-specific hazard ratios and 95% CIs for the association between hypertension outcomes and HIV status for women enrolled at Southern sites of the Women's Interagency HIV Study



Fully adjusted Cox hazard model includes the following variables: age, education, health insurance, smoking, alcohol, substance use, body mass index, history of cardiovascular disease, diabetes, estimated glomerular filtration rate, hepatic fibrosis, aspartate aminotransferase/platelet ratio, hepatitis C, depressive symptoms, and CD4 count.

HARMONIZING RADIAL AND BRACHIAL BLOOD PRESSURE MEASUREMENTS AMONG INDIVIDUALS WITH LARGE ARM CIRCUMFERENCE LIVING WITH OR WITHOUT HIV

by

JESSICA P. BLAIR, MIRJAM-COLETTE KEMPF, JODIE A. DIONNE, ZENORIA CAUSEY-PRUITT, TODD T. BROWN, GYPSYAMBER D'SOUZA, JENNI M. WISE, ELIZABETH A. JACKSON, PAUL MUNTNER, DAVID B. HANNA, KATHRYN ANASTOS, JORGE R. KIZER, MARGARET A. FISCHL, IGHO OFOTOKUN, DEBORAH KONKLE-PARKER, STEPHEN GANGE, ILENE K. BRILL, EMILY B. LEVITAN

In preparation for *Journal of Hypertension*

Format adapted for dissertation

Abstract:

Objective: Proper measurement of blood pressure is important to accurately diagnosis and treat hypertension, especially among people with obesity. We compared radial and brachial blood pressure among participants with a mid-arm circumference >40 cm. Additionally, we developed a regression equation to harmonize radial and previously measured brachial blood pressure.

Study Design and Setting: We evaluated participants with obesity recruited into the Blood Pressure Crosswalk sub-study (2022-2023). Pearson correlations and Bland-Altman plots compared mean differences between radial and brachial blood pressure. Separate linear regression analyses were conducted to harmonize estimated radial and measured brachial blood pressure. We evaluated participants with large arm circumference in the parent Multicenter AIDS Cohort Study/Women's Interagency HIV Study-Combined Cohort Study to obtain hypertension prevalence and control using previously collected brachial and estimated radial blood pressure.

Results: Among the 88 participants in the Blood Pressure Crosswalk sub-study, the mean within-person difference for systolic and diastolic radial and brachial blood pressure was 16.6 mmHg and 13.2 mmHg, respectively (p-value<0.001). Radial and brachial values were highly correlated for both systolic and diastolic blood pressure (p-value<0.01). Among the 341 participants with large arm circumference from the parent study, 75% had hypertension, of which 22% had controlled hypertension based on brachial blood pressure. After applying the regression equation to estimate radial blood pressure, prevalence of hypertension increased to 98% and control decreased to 3%.

Conclusion: Our study showed a strong correlation between radial and brachial blood pressure, but radial values were significantly higher than brachial values. After regression analysis, estimates of hypertension prevalence increased and control decreased for estimated radial blood pressure compared to previously measured brachial blood pressure.

Introduction:

Hypertension is a treatable and highly preventable risk factor for cardiovascular disease, kidney disease, cognitive impairment, and premature mortality.[1,2] To accurately diagnosis, treat, and study hypertension, it is vital to use proper blood pressure (BP) measurement techniques.[3] This includes selecting a BP cuff that fits the individual. When the BP cuff is too small, overestimation of BP can occur.[3-5] In one study, systolic BP increased 2-5 mmHg for every 5 cm increase in mid-arm circumference about 35 cm and diastolic BP increased 1-3 mmHg.[4] Use of poorly fitting BP cuffs and hence mismeasurement of BP is likely to be common among the 42% of United States (US) adults who have obesity because of limitations in or lack of access to BP monitoring equipment designed for individuals with large arm circumference.[6] A recent study conducted in the National Health and Nutrition Examination Survey showed that 40% of US adults required a large cuff (mid-arm circumference 35-44 cm) and 3% required an extra-large cuff (≥45 cm).[3,7]

Prior to 2022, Multicenter AIDS Cohort Study (MACS)/Women's Interagency HIV Study (WIHS)-Combined Cohort Study (MWCCS) exam protocols specified use of thigh BP cuffs on the upper arm among participants with mid-arm circumference >40 cm. Thigh cuffs, which are both wider and longer than cuffs designed for the upper arm, can be problematic for measuring brachial BP if they cover an individual's elbow or armpit and may not fit well for individuals whose upper arms are conical in shape.[8] Therefore, the MWCCS protocol was updated in 2022 to use more recently developed radial cuffs on the forearm for participants with mid-arm circumference >40 cm. Radial BP is significantly higher than BP measured from the brachial artery.[5,9] In one study of

individuals with obesity, the mean radial systolic BP was a 12±10 mmHg higher and diastolic BP was 9±9 mmHg higher than brachial BP.[5] The threshold for defining hypertension is the same at both brachial and radial locations.

The goal of our study was to compare and harmonize radial and brachial BP among participants with a mid-arm circumference >40 cm in select MWCCS sites to inform longitudinal analyses of BP in MWCCS as well as hypertension research and clinical practice among individuals with obesity in other settings. We hypothesized that radial systolic and diastolic BP would be higher than brachial systolic and diastolic BP and that we could develop a regression equation to harmonize radial BP and previously collected brachial BP among individuals with mid-arm circumference >40 cm. In addition, we estimated hypertension prevalence and control using the brachial BP measurements and estimated radial BP among MWCCS participants with large arm circumference. We hypothesized the estimated prevalence of hypertension would increase and control of hypertension would decrease after applying the regression equation.

Methods:

Population:

The MWCCS has previously been described in detail.[10] Briefly, the ongoing prospective study merged MACS and WIHS in 2019 and is primarily funded by the National Heart, Lung, and Blood Institute. Participants are US adults who are at risk for or living with HIV. A major focus of current MWCCS research addresses chronic comorbidities, like cardiovascular disease, which affect people living with HIV.

We included two subgroups of MWCCS participants for the current analyses. First, to compare brachial and radial BP and BP measurement protocols, in 2022-2023 we recruited 88 participants from the Atlanta, GA; Birmingham, AL/Jackson, MS; and Bronx, NY sites for the Blood Pressure (BP) Crosswalk sub-study. MWCCS participants were eligible for the BP Crosswalk sub-study if they were participating in the annual visit during 2022-2023, had a mid-arm circumference >40 cm, and provided written informed consent to participate in additional BP measurements.

Second, when comparing hypertension prevalence and control between measured brachial BP and estimated radial BP, we included MWCCS participants who participated in the annual visit during 2020-2021 and who had mid-arm circumference >40 cm. Participants were chosen during this timeframe because the protocol in MWCCS changed at the end of 2021 to use radial cuffs instead of thigh cuffs for participants with large arm circumferences. Participants were included if they had information to determine prevalence and control of hypertension.

The BP Crosswalk sub-study and the MWCCS were approved by IRBs at participating institutions and the MWCCS executive committee. Participants provided informed consent for the parent study and sub-study. Data necessary to replicate these analyses are available from MWCCS (https://statepi.jhsph.edu/mwccs/work-with-us/, mwccs@jhu.edu). Lead Author (JB) led the BP Crosswalk sub-study and had full access to all data in this analysis and takes full responsibility for its integrity and data analysis.

Blood pressure measurement in the MWCCS parent study:

Prior to 2022, thigh cuffs were used to measure BP on the upper arm for participants with mid-arm circumference >40 cm, which was measured at the midpoint from shoulder to elbow with the right arm held horizontal. The two mid-arm circumference measurements were recorded and repeated if the difference was greater than 0.7 cm.

Prior to BP collection, participants sat for five minutes in a quiet room with their feet flat on the floor. An automated Dinamap monitor (Dinamap Procare Series; GE Medical Systems, Chicago, Illinois, USA) was used to collect brachial BP measurements. The cuff was placed with tubes facing down along the brachial artery. A set of three measurements were collected with 60 seconds in between each recording. The participant's arm was held overhead for the first five seconds between each recording. Measurements were collected from the right arm, which were flexed with palms facing upward at heart level, unless circumstances prohibited use of the right arm.

Starting in 2022, radial cuffs and automated Dinamap monitors were used for measurement of BP among participants with mid-arm circumference >40 cm. The radial cuff was placed so that tubes faced upward along the radial artery. Participants sat for five minutes in a quiet room with their feet flat on the floor and three measurements were taken with a minute between each measurement.

Blood pressure measurement in the Blood Pressure Crosswalk sub-study:

The University of Alabama at Birmingham Hypertension Center provided training in BP measurement for each participating site, specifically on proper placement of the

radial cuff and brachial thigh cuff to standardize across sites and reduce measurement error. Each site conducted mock study visits and received certification before recruiting participants.

Mid-arm circumference for upper arm was collected in the same manner as the parent study. Forearm circumference, which was measured one centimeter below the elbow, was recorded using two measurements and repeated if the difference was also greater than 0.7 cm. Participants sat quietly for five minutes prior to BP collection obtained using an automated Dinamap monitor (Dinamap Procare Series; GE Medical Systems, Chicago, Illinois, USA). Radial and brachial BP were measured in random order in a 1:1 ratio, which was defined beforehand using SAS 9.4. A set of three measurements were collected for both the radial and brachial arteries with 60 seconds in between each recording. As in the parent study, the participant's arm was raised for the first five seconds between each recording. For both sets of measurements, the arm was slightly flexed with palms faced upward close to heart level.

Hypertension:

Prevalence of hypertension was defined as systolic or diastolic BP ≥130/80 mmHg or self-reported current use of antihypertensive medication with self-reported awareness of hypertension diagnosis. Among participants with hypertension, control was defined as systolic and diastolic BP <130/80 mmHg.

Covariates:

The baseline variables collected through questionnaires were sex assigned at birth (male/female), race, and highest level of education. Race was categorized based on the 2018 National Institutes of Health definition as American Indian/Alaskan Native, Asian, Native Hawaiian/Pacific Islander, Black/African American, White, other, and multiracial.[11] Due to small sample sizes, especially for the BP Crosswalk sub-cohort, we categorized race as Black and non-Black for analyses. Highest level of education was categorized as less than high school, high school graduate, some college, and college graduate or higher. Lifetime substance use was also captured at baseline with self-reported questionnaires. We categorized substance use as none, marijuana only, or illicit drugs, which included crack, cocaine, heroin, opiates, prescription drug abuse, or injected drugs.

The following variables were collected at every visit: current age in years, body mass index (BMI, kg/m^2), smoking status (never, former, current), HIV status, and self-reported current use of antihypertensive medication. Smoking status was obtained through questionnaires and HIV serostatus was verified with medical laboratory results. For people living with HIV (PLWH), we also collected current antiretroviral therapy, which was self-reported as yes/no.

During the BP Crosswalk sub-cohort exam, participants were asked if they smoked or consumed caffeine within 30 minutes prior to BP measurements or if they exercised vigorously on the day of the visit because these behaviors transiently increase BP.

Statistical methods:

We described participant characteristics by sex assigned at birth, age group (<45 years and ≥45 years), race, and HIV status using means and standard deviations or N (%). The averages of the three BP measures were calculated for each participant for radial systolic and diastolic BP and brachial systolic and diastolic BP.

Among BP Crosswalk sub-study participants, Pearson correlations between mean radial and brachial systolic BP and mean radial and brachial diastolic BP were calculated. Paired t-tests were utilized to examine differences between mean radial and brachial BP measurements. Bland-Altman plots were used to evaluate if differences between the radial and brachial measurements depended on the average values. We used independent t-tests to assess whether differences between radial and brachial BP varied by sex assigned at birth, age group, race, and HIV status.

We examined the relationship between radial and brachial BP using separate linear regression analyses for systolic and diastolic BP with brachial values as the independent variable because they were previously collected in past study visits. The crude regression model only included brachial BP. Each model afterwards added an additional covariate that had the potential to affect differences in BP: sex assigned at birth, age, current antihypertensive medication use, mid-arm circumference, and BMI. The best fit models for systolic and diastolic BP were chosen based on adjusted r-squared, mean square error, and significance of independent variables.

To evaluate the relationship between increasing upper arm circumference and high BP, we categorized mid-arm circumference as 40-44 cm, 44.1-50 cm, and >50 cm based on American Heart Association (AHA) and American Medical Association (AMA)

recommendations of adult cuff size.[3] As a sensitivity analysis, we excluded participants with a mid-arm circumference >50 cm and forearm circumference <26 cm or >36 cm based on recommended threshold measurements for the Dinamap cuffs.[3,12] We conducted another sensitivity analysis excluding participants who answered yes to exercising, smoking, or consuming caffeine prior to BP measurement. We also assessed the collinearity between mid-arm circumference and BMI.

Among MWCCS participants with large arm circumference, we calculated hypertension prevalence and control utilizing brachial BP collected during visit 101 in MWCCS. The best fit models for systolic and diastolic BP were then applied to the data collected at visit 101 to obtain estimated radial measurements. Hypertension prevalence and control were again calculated using the newly estimated radial systolic and diastolic BP. These hypertension outcomes were stratified by sex assigned at birth, age group, race, and HIV status and differences were compared using chi-square and Fisher's exact tests.

Results:

BP Crosswalk sub-study comparing radial and brachial measurements:

There were 88 participants recruited in the BP Crosswalk Study, of whom 71 (81%) were assigned female at birth, 79 (90%) were Black, and 63 (72%) were PLWH. See Supplemental Figure 1A for enrollment by site. None of the study participants were currently pregnant or breastfeeding. Participants assigned female at birth were typically older, more likely to use antihypertensive medication, and have lower prevalence of HIV compared to participants assigned male at birth (Table 1A). Participants <45 years were

more likely to be Black, less likely to be diagnosed with HIV, and have a mid-arm circumference >50 cm compared to participants ≥45 years. See Table 1A for the summary of remaining demographics for the BP Crosswalk sub-study and Supplemental Table 1A for characteristics stratified by race and HIV status.

The mean systolic BP for radial and brachial arteries were 148.3 ± 19.8 and 131.8 ± 18.4 mmHg, respectively. The mean within-person difference was 16.5 mmHg [95% CI=(12.9, 20.1); p-value<0.001]. The mean diastolic BP for radial and brachial arteries were 85.2 ± 12.6 and 72.0 ± 12.5 mmHg, respectively. The mean within-person difference was 13.2 mmHg [95% CI=(11.1, 15.3); p-value<0.001]. The Pearson correlation between radial and brachial systolic BP was r=0.60 and diastolic BP was r=0.69 (p-value<0.01, Figure 1A). We found correlation between the bias (difference between radial and brachial BP) and magnitude (average of radial and brachial BP) for systolic BP (r=0.29, p-value=0.005). However, we did not see a statistically significant correlation between bias and magnitude for diastolic BP (r=0.04, p-value=0.70) as seen in Figure 1B.

Participants assigned female at birth had a systolic 14.0 mmHg [95% CI=(10.4, 17.6)] average difference between radial and brachial cuffs while participants assigned male at birth had a 26.7 mmHg [95% CI=(16.3, 37.2)] average difference (p-value=0.005). We did not see statistically significant variation in differences between cuffs by age group, race, or HIV status (Supplemental Table 2).

BP Crosswalk sub-study harmonizing radial and brachial measurements:

The linear regression analyses for systolic BP are shown in Table 2. We found no collinearity between mid-arm circumference and BMI (variance inflation factor=1). Considering the highest adjusted r-squared and lowest mean square error, Model 2, including brachial BP, sex assigned at birth, and age, is the best fit for estimated radial systolic BP. The exploratory analysis including mid-arm circumference categorized as 40-44 cm, 44.1-50 cm, and >50 cm, showed similar model prediction (Supplemental Table 3). When examining the regression analyses excluding participants with mid-arm circumference >50 cm or forearm circumference <26 cm or >36 cm (16 participants excluded), Model 5 was the best fit, including brachial BP, sex assigned at birth, age, antihypertensive medication use, mid-arm circumference, and BMI (Supplemental Table 4). The sensitivity analysis excluding participants who answered yes to smoking, consuming caffeine, or exercising vigorously on the day of exam (7 participants excluded) was similar to the overall study population (Supplemental Table 5).

The linear regression analyses for diastolic BP are shown in Table 3. The best fit for estimated radial diastolic BP is Model 2 including brachial BP, sex assigned at birth, and age based on the highest adjusted r-squared and lowest mean square error. The exploratory analysis of categorizing mid-arm circumference as 40-44 cm, 44.1-50 cm, and >50 cm, showed similar model prediction (Supplemental Table 6). Model 2 remained the best fit when participants were excluded based on mid-arm circumference >50 cm or forearm circumference <26 cm or >36 cm (Supplemental Table 7). The sensitivity analysis excluding participants who answered yes to smoking, consuming caffeine, or

exercising vigorously on the day of exam was similar to the overall study population (Supplemental Table 8).

Hypertension prevalence and control among the MWCCS sub-cohort with large mid-arm circumference estimating radial blood pressure:

As of December 2023, there were 4548 participants enrolled in MWCCS (Supplemental Figure 1B). We excluded 1211 participants who did not participate in visit 101. Participants with a mid-arm circumference ≤40 cm (n=2989) and those missing blood pressure measurements (n=7) were also excluded. Our final sample size for the MWCCS sub-cohort was 341 participants, of whom 299 (88%) were assigned female at birth, 289 (85%) were Black, and 235 (69%) were PLWH (Table 1B). Participants assigned female at birth in the MWCCS sub-cohort were more likely to have a mid-arm circumference >50 cm, less likely to use antihypertensive medication, and have higher prevalence of HIV compared to participants assigned male at birth. See Table 1B of remaining demographics for the MWCCS sub-cohort and Supplemental Table 1B for characteristics stratified by race and HIV status.

Using previously collected brachial BP measurements for the MWCCS sub-cohort, 254/341 (74.5%) of participants had hypertension and 55/254 (21.7%) of those with hypertension had it under control. Prevalence of hypertension using brachial BP was higher among participants aged 45 years and older (Table 4A). There were no significant differences in hypertension prevalence or control by race or HIV status (Supplemental Table 9A). After applying the radial BP regression equation to the MWCCS cohort using Model 2 with independent variables of brachial BP, sex assigned at birth, and age, we

found predicted prevalence of hypertension in 334/341 (98%) of participants. We found predicted control in 11/334 (3.3%) of participants with hypertension. There were no significant differences in hypertension prevalence or control by sex assigned at birth, age group, race, or HIV status when using estimated radial BP (Table 4B and Supplemental Table 9B).

Discussion:

In this study population, radial and brachial BP were strongly correlated, but radial BP was substantially higher than brachial BP. Furthermore, we found correlation between the bias (difference between radial and brachial BP) and magnitude (average of radial and brachial BP) for systolic BP but not for diastolic BP. The difference between radial and brachial systolic BP was greater for participants assigned male at birth than participants assigned female at birth. After applying the best fit model to estimate radial systolic and diastolic BP, the prevalence of hypertension was higher, and the prevalence of hypertension control was much lower compared to measured brachial BP values.

The gold standard for capturing blood pressure is intra-arterial measurements, which are invasive and not feasible for most clinical and research settings.[13,14] One study found that 46% of participants had intra-arterial radial and brachial systolic differences of >5 mmHg while 14% had >15 mmHg differences, with radial BP averaging higher than brachial BP.[14] An alternative to the invasive measurements is automated oscillometric devices. However, a majority of clinical settings do not measure arm circumference to select the correct blood pressure cuff.[15] A too small cuff can lead to falsely elevated BP readings while a too large cuff can lead to falsely low BP readings.[16,17] A recently

published randomized trial comparing readings from too-small and too-large cuffs to appropriately sized cuffs found that participants who required a large cuff had higher BP readings [mean systolic difference of 4.8 mmHg, 95% CI=(3.0, 6.6)] compared to the regular cuff size used.[17] Additionally, participants who required an extra-large cuff (>40 cm) had mean systolic BP difference of 19.5 mmHg [95% CI=(16.1, 22.9)] compared to the regular cuff size.[17] In these cases, the regular sized cuff led to falsely elevated BP because the cuff size was too small.

Sometimes oscillometric measurement of brachial BP is not ideal if the available cuffs are too small for the individual's arm circumference or too long for the upper arm. In these cases, the use of a radial cuff on the forearm is a good substitute to obtain blood pressure.[16] However, studies using both intra-arterial and oscillometric BP have shown that radial BP is typically higher than brachial BP.[5,16,18,19] Our study showed a mean difference of 16.5 mmHg for systolic BP between radial and brachial arteries and a mean difference of 13.2 mmHg for diastolic BP. Our findings were similar to another published study that found 12 mmHg mean difference between systolic radial and brachial BP and 9 mmHg difference for diastolic values (p-value<0.05).[5] The current AHA recommended threshold of ≥130/80 mmHg does not provide much guidance on how to account for higher radial BP when diagnosing and treating hypertension. Our Pearson correlation showed that radial and brachial BPs are highly correlated, and our paired t-tests revealed significant differences between radial and brachial measurements. Other studies have found a correlation of 0.9 for systolic BP and 0.8 for diastolic BP between the two locations of cuffs.[16,20]

Our manuscript adds to current literature by focusing on groups underrepresented in research. Participants in MWCCS are either at elevated risk or living with HIV, and individuals assigned female at birth and Black individuals were majorities in this study population. There are few published studies that have examined how to harmonize radial and brachial measurements, especially among individuals with obesity. Additionally, these studies did not test for differential performance of radial and brachial cuffs by sex assigned at birth, age, race, or HIV status.[16,17] This manuscript is not without its limitations. Neither BP measurement approach used in this study is the gold standard. However, the regression equations help with understanding how to study longitudinal BP in individuals with obesity given the change in protocol in 2022. Due to the small sample size of the BP Crosswalk Study sub-cohort and limited number of participants assigned male at birth, there might not be enough power to detect statistically significant differences. Some variables that may be predictive of estimated radial BP, such as smoking/consuming caffeine prior to exam, exercising vigorously on the day of exam, and forearm circumference, were not collected during visit 101 in MWCCS. Therefore, they were not included in the prediction models for radial BP. However, these characteristics are often not available in clinical settings.

The prevalence of obesity has increased in the US from 31% in 2000 to 42% in 2020; adults aged 40 to 59 had the highest prevalence of obesity.[6] It is therefore crucial that clinical settings should utilize the appropriate cuff sizes and specialize BP readings based on individual arm circumference. Our manuscript, and several published studies, have shown a significant difference between BP collected at the radial artery and brachial artery, suggesting that a new threshold may be needed to accurately diagnose

hypertension and monitor hypertension treatment when BP is measured from the radial artery.

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Table 1. Characteristics of study population for the Multicenter AIDS Cohort Study/Women's Interagency HIV Study-Combined Cohort Study by sex assigned at birth and age group

A. Participants in BP Crosswalk sub-study included in comparison of radial and brachial measurements					
	Overall	Female	Male	<45 years	≥ 45 years
Number	*88*	*71*	*17*	*35*	*53*
Age, mean ± SD	48.3 ± 9.1	49.7 ± 8.8	42.5 ± 8.2	---	---
Assigned female at birth	72 (80.7)	---	---	24 (68.6)	47 (88.7)
Black	79 (89.8)	64 (90.1)	15 (88.2)	35 (100.0)	44 (83.0)
Education					
<HS	23 (26.1)	20 (28.2)	3 (17.7)	8 (22.9)	15 (28.3)
HS graduate	21 (23.9)	16 (22.5)	5 (29.4)	5 (14.3)	16 (30.2)
Some college	37 (42.1)	31 (43.7)	6 (35.3)	16 (45.7)	21 (39.6)
≥ College graduate	7 (8.0)	4 (5.6)	3 (17.7)	6 (17.1)	1 (1.9)
Substance use					
None	36 (40.9)	31 (43.7)	5 (29.4)	14 (40.0)	22 (41.5)
Marijuana only	7 (8.0)	2 (2.8)	5 (29.4)	4 (11.4)	3 (5.7)
Illicit drugs	45 (51.1)	38 (53.5)	7 (41.2)	17 (48.6)	28 (52.8)
Smoking status					
Never	33 (37.5)	27 (38.0)	6 (35.3)	14 (40.0)	19 (35.9)
Former	37 (42.1)	29 (40.9)	8 (47.1)	14 (40.0)	23 (43.4)
Current	18 (20.5)	15 (21.1)	3 (17.7)	7 (20.0)	11 (20.8)
Mid-arm circumference					
40-44 cm	48 (54.6)	38 (53.5)	10 (58.8)	15 (42.9)	33 (62.26)
44.1-50 cm	29 (33.0)	24 (33.8)	5 (29.4)	12 (34.3)	17 (32.1)
>50 cm	11 (12.5)	9 (12.7)	2 (11.8)	8 (22.9)	3 (5.7)
Mid-arm circumference, mean ± SD	44.5 ± 3.7	44.6 ± 3.7	44.0 ± 3.7	45.4 ± 4.0	43.8 ± 3.2
BMI, mean ± SD	47.9 ± 10.2	48.3 ± 9.0	46.0 ± 14.6	49.9 ± 11.2	46.5 ± 9.4
Current antihypertensive medication use	40 (45.5)	36 (50.7)	4 (23.5)	15 (42.9)	25 (47.2)
PLWH	63 (71.6)	50 (70.4)	13 (76.5)	23 (65.7)	40 (75.5)
Current ART usage[a]	61 (96.8)	49 (98.0)	12 (92.3)	23 (100.0)	38 (95.0)

B. Participants with large arm circumference in MWCCS included in comparison of hypertension prevalence and control using radial and brachial measurements					
	Overall	Female	Male	<45 years	≥ 45 years
Number	*341*	*299*	*42*	*108*	*233*
Age, mean ± SD	49.7 ± 9.1	49.9 ± 8.8	47.7 ± 10.5	---	---
Assigned female at birth	299 (87.7)	---	---	92 (85.2)	207 (88.8)
Black	289 (84.8)	253 (84.6)	36 (85.7)	97 (89.8)	192 (82.4)
Education					
<HS	87 (25.5)	86 (28.8)	1 (2.4)	23 (21.3)	64 (27.5)
HS graduate	113 (33.1)	98 (32.8)	15 (35.7)	27 (25.0)	86 (36.9)
Some college	103 (30.2)	95 (31.8)	8 (19.1)	43 (39.8)	60 (25.8)
≥ College graduate	38 (11.1)	20 (6.7)	18 (42.9)	15 (13.9)	23 (9.9)
Substance use					
None	147 (43.5)	137 (46.0)	10 (25.0)	44 (41.9)	103 (44.2)
Marijuana only	21 (6.2)	11 (3.7)	10 (25.0)	9 (8.6)	12 (5.2)
Illicit drugs	170 (50.3)	150 (50.3)	20 (50.0)	52 (49.5)	118 (50.6)
Smoking status					
Never	126 (37.1)	110 (36.9)	16 (38.1)	41 (38.3)	85 (36.5)
Former	134 (39.4)	118 (39.6)	16 (38.1)	39 (36.5)	95 (40.8)
Current	80 (23.5)	70 (23.5)	10 (23.8)	27 (25.2)	53 (22.8)
Mid-arm circumference					
40-44 cm	192 (56.3)	164(54.9)	28 (66.7)	58 (53.7)	134 (57.5)
44.1-50 cm	105 (30.8)	93 (31.1)	12 (28.6)	34 (31.5)	71 (30.5)
>50 cm	44 (12.9)	42 (14.1)	2 (4.8)	16 (14.8)	28 (12.0)
Mid-arm circumference, mean ± SD	44.7 ± 4.4	44.9 ± 4.5	43.1 ± 2.8	44.9 ± 4.1	44.6 ± 4.5
BMI, mean ± SD	45.3 ± 8.4	45.9 ± 8.4	40.9 ± 6.9	46.1 ± 8.6	44.9 ± 8.3
Current antihypertensive medication use	156 (45.9)	136 (45.6)	20 (47.6)	29 (27.1)	127 (54.5)
PLWH	235 (68.9)	210 (70.2)	25 (59.5)	73 (67.6)	162 (69.5)
Current ART usage[a]	227 (96.6)	203 (96.7)	24 (96.0)	72 (98.6)	155 (95.7)

Data are presented as mean ± SD or No. (%).

Abbreviations: ART, antiretroviral therapy; BMI, body mass index (kg/m^2); cm, centimeters; HS, high school; PLWH, people living with HIV.

[a]Current ART usage among PLWH.

Table 2. Linear regression equations with beta estimates for radial systolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Crude	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	62.5	68.6	82.9	82.5	93.0	91.2
Brachial (mmHg)	0.65*	0.67*	0.65*	0.65*	0.66*	0.65*
Assigned female at birth	---	-11.3*	-9.2*	-9.6*	-9.4*	-10.0*
Age (years)	---	---	-0.28	-0.28	-0.30	-0.26
Antihypertensive med.	---	---	---	1.4	1.6	1.6
Mid-arm circumference (cm)	---	---	---	---	-0.23	-0.45
BMI (kg/m^2)	---	---	---	---	---	0.24
R-squared	0.36	0.42	0.43	0.43	0.43	0.44
Adjusted R-squared	0.36	0.40	0.41	0.40	0.40	0.40
Mean square error	251.6	234.2	231.1	233.4	235.5	233.2
Number observations	88					

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; med, medication.

Table 3. Linear regression equations with beta estimates for radial diastolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Crude	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	35.2	40.0	54.5	54.5	47.0	47.8
Brachial (mmHg)	0.69*	0.67*	0.62*	0.62*	0.63*	0.60*
Assigned female at birth	---	-3.6	-2.1	-2.2	-2.4	-3.0
Age (years)	---	---	-0.25*	-0.25*	-0.23	-0.21
Antihypertensive med.	---	---	---	0.40	0.24	0.30
Mid-arm circumference (cm)	---	---	---	---	0.14	-0.04
BMI (kg/m^2)	---	---	---	---	---	0.18
R-squared	0.47	0.48	0.51	0.51	0.51	0.53
Adjusted R-squared	0.47	0.47	0.49	0.48	0.48	0.49
Mean square error	85.0	84.0	80.4	81.3	82.1	80.3
Number observations	88					

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; med, medication.

Table 4. Prevalence and control of hypertension in MWCCS sub-cohort with large arm circumference by sex assigned at birth and age group

A. Measured brachial blood pressure						
	Female	Male	*P* value[a]	<45 years	≥45 years	*P* value[a]
Number	*299*	*42*		*108*	*233*	
Prevalence	220 (73.6)	34 (81.0)	0.30	67 (62.0)	187 (80.3)	<0.001
Number	*220*	*34*		*67*	*187*	
Control	52 (23.6)	3 (8.8)	0.05	10 (14.9)	45 (24.1)	0.12
B. Estimated radial blood pressure						
	Female	Male	*P* value[b]	<45 years	≥45 years	*P* value[b]
Number	*299*	*42*		*108*	*233*	
Prevalence	292 (97.7)	42 (100.0)	0.60	107 (99.0)	227 (97.4)	0.44
Number	*292*	*42*		*107*	*227*	
Control	11 (3.8)	0 (0.0)	0.37	2 (1.9)	9 (4.0)	0.51

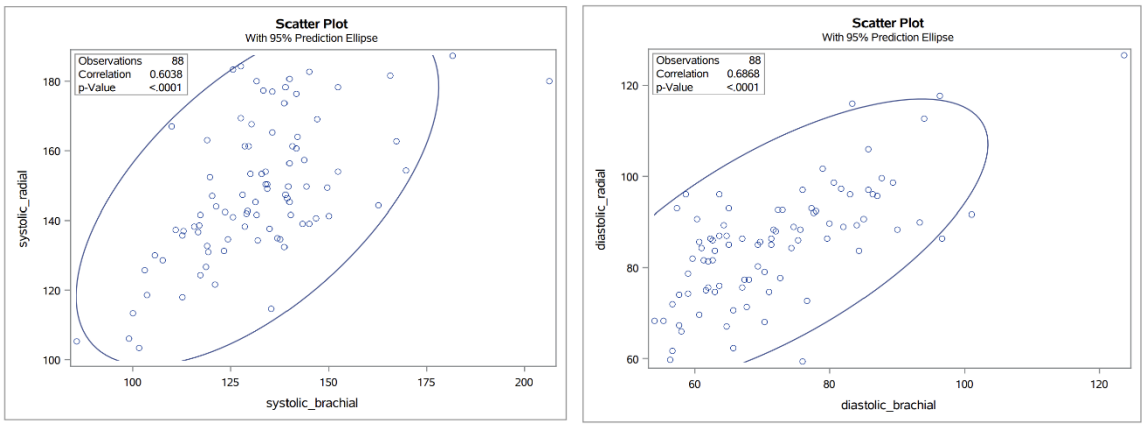
Data are presented as No. (%).

[a]Chi-square p-value.

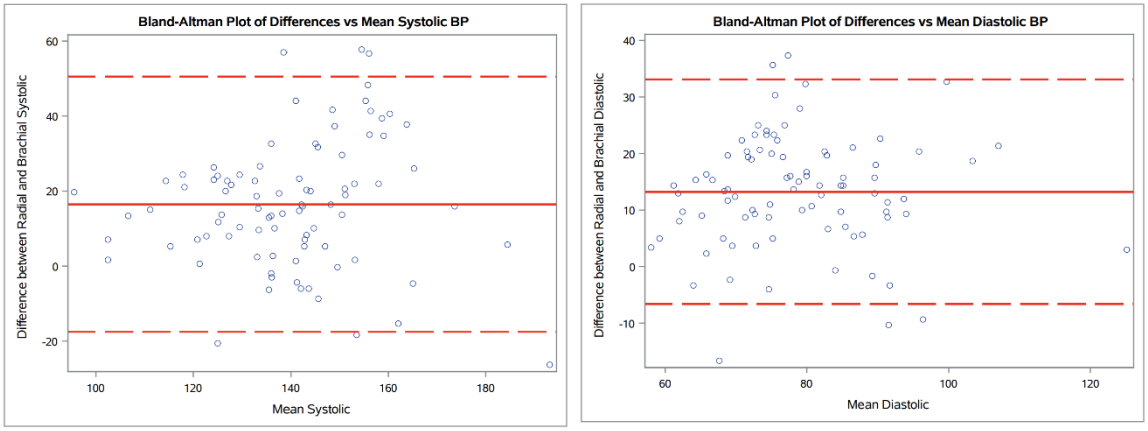
[b]Fisher's exact p-value.

Figure 1. Pearson correlations and Bland-Altman scatter plots of mean systolic blood pressure and diastolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

A. Pearson correlations



B. Bland-Altman scatter plots



X-axis and y-axis have units of mmHg.

Reference line at mean of difference in solid red; reference line at ±2 standard deviations of mean of difference in dashed red.

Table S1. Characteristics of study population for the Multicenter AIDS Cohort Study/Women's Interagency HIV Study-Combined Cohort Study by race and HIV status

A. Participants in BP Crosswalk sub-study included in comparison of radial and brachial measurements				
	Black	Non-Black	PLWH	PLWOH
Number	*79*	*9*	*63*	*25*
Age, mean ± SD	47.6 ± 9.2	54.4 ± 4.9	49.3 ± 9.6	45.7 ± 7.1
Assigned female at birth	64 (81.0)	7 (77.8)	50 (79.4)	21 (84.0)
Black	---	---	56 (88.9)	23 (92.0)
Education				
<HS	21 (26.6)	2 (22.2)	16 (25.4)	7 (28.0)
HS graduate	17 (21.5)	4 (44.4)	16 (25.4)	5 (20.0)
Some college	34 (43.0)	3 (33.3)	25 (39.7)	12 (48.0)
≥ College graduate	7 (8.9)	0 (0.0)	6 (9.5)	1 (4.0)
Substance use				
None	32 (40.5)	4 (44.4)	23 (36.5)	13 (52.0)
Marijuana only	7 (8.9)	0 (0.0)	6 (9.5)	1 (4.0)
Illicit drugs	40 (50.6)	5 (55.6)	34 (54.0)	11 (44.0)
Smoking status				
Never	28 (35.4)	5 (55.6)	23 (36.5)	10 (40.0)
Former	37 (46.8)	0 (0.0)	28 (44.4)	9 (36.0)
Current	14 (17.7)	4 (44.4)	12 (19.1)	6 (24.0)
Mid-arm circumference				
40-44 cm	45 (57.0)	3 (33.3)	36 (57.1)	12 (48.0)
44.1-50 cm	24 (30.4)	5 (55.6)	21 (33.3)	8 (32.0)
>50 cm	10 (12.7)	1 (11.1)	6 (9.5)	5 (20.0)
Mid-arm circumference, mean ± SD	44.4 ± 3.7	45.3 ± 3.1	44.1 ± 3.6	45.3 ± 3.8
BMI, mean ± SD	47.5 ± 10.0	51.4 ± 12.2	47.4 ± 11.1	49.0 ± 7.6
Current antihypertensive medication use	34 (43.0)	6 (66.7)	32 (50.8)	8 (32.0)
PLWH	56 (70.9)	7 (77.8)	---	---
Current ART usage[a]	54 (96.4)	7 (100.0)	61 (96.8)	---
B. Participants with large arm circumference in MWCCS included in comparison of hypertension prevalence and control using radial and brachial measurements				
	Black	Non-Black	PLWH	PLWOH
Number	*289*	*52*	*235*	*106*
Age, mean ± SD	49.0 ± 9.0	53.3 ± 9.0	49.7 ± 9.0	49.7 ± 9.3
Assigned female at birth	253 (87.5)	46 (88.5)	210 (89.4)	89 (84.0)
Black	---	---	199 (84.7)	90 (84.9)
Education				
<HS	78 (27.0)	9 (17.3)	59 (25.1)	28 (26.4)
HS graduate	93 (32.2)	20 (38.5)	86 (36.6)	27 (25.5)

Some college	88 (30.5)	15 (28.9)	65 (27.7)	38 (35.9)
≥ College graduate	30 (10.4)	8 (15.4)	25 (10.6)	13 (12.3)
Substance use				
None	127 (44.4)	20 (38.5)	110 (47.2)	37 (35.2)
Marijuana only	18 (6.3)	3 (5.8)	12 (5.2)	9 (8.6)
Illicit drugs	141 (49.3)	29 (55.8)	111 (47.6)	59 (56.2)
Smoking status				
Never	105 (36.5)	21 (40.4)	93 (39.6)	33 (31.4)
Former	117 (40.6)	17 (32.7)	89 (37.9)	45 (42.9)
Current	66 (22.9)	14 (26.9)	53 (22.6)	27 (25.7)
Mid-arm circumference				
40-44 cm	168 (58.1)	24 (46.2)	129 (54.9)	63 (59.4)
44.1-50 cm	82 (28.4)	23 (44.2)	74 (31.5)	31 (29.3)
>50 cm	39 (13.5)	5 (9.6)	32 (13.6)	12 (11.3)
Mid-arm circumference, mean ± SD	44.6 ± 4.3	45.0 ± 4.6	44.8 ± 4.6	44.3 ± 3.7
BMI, mean ± SD	45.2 ± 8.4	45.7 ± 8.7	45.5 ± 8.6	44.7 ± 8.1
Current antihypertensive medication use	137 (47.6)	19 (36.5)	115 (48.9)	41 (39.1)
PLWH	199 (68.9)	36 (69.2)	---	---
Current ART usage[a]	192 (96.5)	35 (97.2)	227 (96.6)	---

Data are presented as mean ± SD or No. (%).

Abbreviations: ART, antiretroviral therapy; BMI, body mass index (kg/m^2); cm, centimeters; HS, high school; PLWH, people living with HIV.

[a]Current ART usage among PLWH.

Table S2. Mean difference in blood pressure for radial and brachial cuffs by sex assigned at birth, age group, race, and HIV status among participants in the Blood Pressure Crosswalk sub-study

	Female			*Male*			
	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	*P* value[b]
Average systolic BP, mmHg	146.7 ± 19.5	132.6 ± 19.5	14.0 (10.40, 17.6)	155.0 ± 20.2	128.3 ± 12.6	26.7 (16.3, 37.2)	0.005
Average diastolic BP, mmHg	83.6 ± 11.5	70.7 ± 12.4	13.0 (10.6, 15.4)	91.9 ± 15.1	77.6 ± 11.6	14.3 (9.5, 19.0)	0.63
	<45 years			*≥45 years*			
	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	*P* value[b]
Average systolic BP, mmHg	153.1 ± 22.0	133.7 ± 20.8	19.4 (13.0, 25.7)	145.1 ± 17.7	130.5 ± 16.6	14.6 (10.2, 19.0)	0.20
Average diastolic BP, mmHg	90.5 ± 13.6	75.1 ± 14.7	15.4 (11.9, 18.8)	81.8 ± 10.7	70.0 ± 10.4	11.8 (9.1, 14.5)	0.10
	Black			*Non-Black*			
	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	*P* value[b]
Average systolic BP, mmHg	149.1 ± 19.7	132.0 ± 18.8	17.2 (13.3, 21.0)	140.8 ± 20.1	130.5 ± 15.2	10.3 (-1.2, 21.7)	0.25
Average diastolic BP, mmHg	86.1 ± 12.6	72.3 ± 12.8	13.8 (11.5, 15.9)	78.0 ± 11.1	69.3 ± 9.1	8.7 (0.4, 16.9)	0.15
	PLWH			*PLWOH*			
	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	Radial BP cuff	Brachial BP cuff	BP difference[a] (95% CI)	*P* value[b]
Average systolic BP, mmHg	147.9 ± 21.0	130.7 ± 18.4	17.2 (12.9, 21.5)	149.3 ± 16.6	134.7 ± 18.4	14.6 (7.6, 21.7)	0.53
Average diastolic BP, mmHg	83.7 ± 12.5	71.3 ± 11.1	12.5 (10.1, 14.8)	89.1 ± 12.2	73.9 ± 15.5	15.1 (10.5, 19.8)	0.26

Data are presented as mean ± SD.

Abbreviations: BP, blood pressure; PLWH, people living with HIV; PLWOH, people living without HIV.

[a]Average difference of radial – brachial.

[b]Pooled equality of variances.

Table S3. Linear regression equation for categorical mid-arm circumference with beta estimates for radial systolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Categorical mid-arm circumference[a]
Intercept	69.1
Brachial (mmHg)	0.67*
Assigned female at birth	-10.4*
Age (years)	-0.24
Antihypertensive medication	2.0
Mid-arm circumference (cm)	---
44.1 – 50 cm	-5.5
>50 cm	-3.0
BMI (kg/m^2)	0.25
R-squared	0.45
Adjusted R-squared	0.41
Mean square error	232.7
Number observations	88

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; cm, centimeters.

[a]Utilized full Model 5.

Table S4. Linear regression equations excluding participants with mid-arm circumference >50 cm or forearm circumference <26 cm or >36 cm with beta estimates for radial systolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Crude	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	59.0	65.5	78.7	78.8	101.2	102.9
Brachial (mmHg)	0.68*	0.69*	0.67*	0.67*	0.69*	0.67*
Assigned female at birth	---	-9.5*	-7.8	-7.7	-7.4	-8.3
Age (years)	---	---	-0.27	-0.27	-0.28	-0.20
Antihypertensive med.	---	---	---	-0.3	0.05	0.19
Mid-arm circumference (cm)	---	---	---	---	-0.57	-1.0
BMI (kg/m^2)	---	---	---	---	---	0.38
R-squared	0.40	0.43	0.44	0.45	0.45	0.48
Adjusted R-squared	0.39	0.42	0.42	0.42	0.41	0.43
Mean square error	259.4	248.4	245.7	249.3	250.7	240.7
Number observations	72					

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; med, medication.

Table S5. Linear regression equations excluding participants who smoked, consumed caffeine, or exercised vigorously on day of exam with beta estimates for radial systolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Crude	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	62.4	69.3	81.6	81.1	90.4	88.4
Brachial (mmHg)	0.65*	0.68*	0.67*	0.67*	0.68*	0.67*
Assigned female at birth	---	-12.9*	-10.5*	-10.8*	-10.6*	-11.2*
Age (years)	---	---	-0.27	-0.27	-0.29	-0.26
Antihypertensive med.	---	---	---	1.5	1.7	1.8
Mid-arm circumference (cm)	---	---	---	---	-0.21	-0.41
BMI (kg/m^2)	---	---	---	---	---	0.23
R-squared	0.35	0.42	0.43	0.43	0.44	0.45
Adjusted R-squared	0.35	0.40	0.41	0.40	0.40	0.40
Mean square error	257.9	235.6	232.2	234.7	237.2	235.1
Number observations	81					

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; med, medication.

Table S6. Linear regression equation for categorical mid-arm circumference with beta estimates for radial diastolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Categorical mid-arm circumference[a]
Intercept	43.1
Brachial (mmHg)	0.62*
Assigned female at birth	-3.0
Age (years)	-0.19
Antihypertensive medication	0.58
Mid-arm circumference (cm)	---
44.1 – 50 cm	-3.5
>50 cm	0.83
BMI	0.20
R-squared	0.55
Adjusted R-squared	0.51
Mean square error	78.3
Number observations	88

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; med, medication.

[a]Utilized full Model 5.

Table S7. Linear regression equations excluding participants with mid-arm circumference >50 cm or forearm circumference <26 cm or >36 cm with beta estimates for radial diastolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Crude	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	30.3	33.6	49.1	49.1	59.4	61.8
Brachial (mmHg)	0.75*	0.73*	0.67*	0.67*	0.67*	0.65*
Assigned female at birth	---	-2.5	-1.3	-1.0	-0.86	-1.4
Age (years)	---	---	-0.24	-0.24	-0.25	-0.23
Antihypertensive med.	---	---	---	-0.82	-0.67	-0.54
Mid-arm circumference (cm)	---	---	---	---	-0.23	-0.45
BMI (kg/m^2)	---	---	---	---	---	0.17
R-squared	0.53	0.54	0.56	0.56	0.57	0.58
Adjusted R-squared	0.53	0.53	0.54	0.54	0.53	0.54
Mean square error	80.6	80.8	78.0	79.0	79.8	78.3
Number observations	72					

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; med, medication.

Table S8. Linear regression equations excluding participants who smoked, consumed caffeine, or exercised vigorously on day of exam with beta estimates for radial diastolic blood pressure among participants in the Blood Pressure Crosswalk sub-study

	Crude	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	32.2	39.1	51.8	51.8	42.7	43.3
Brachial (mmHg)	0.73*	0.69*	0.65*	0.66*	0.66*	0.64*
Assigned female at birth	---	-4.9	-3.5	-3.3	-3.4	-4.0
Age (years)	---	---	-0.23*	-0.23*	-0.21	-0.19
Antihypertensive med.	---	---	---	-0.29	-0.52	-0.43
Mid-arm circumference (cm)	---	---	---	---	0.17	0.01
BMI (kg/m^2)	---	---	---	---	---	0.16
R-squared	0.51	0.53	0.55	0.55	0.56	0.57
Adjusted R-squared	0.51	0.52	0.54	0.53	0.53	0.54
Mean square error	80.1	77.4	74.5	75.5	76.1	74.5
Number observations	81					

* Indicates significance at the 95% level.

Abbreviations: BMI, body mass index; med, medication.

Table S9. Prevalence and control of hypertension in MWCCS sub-cohort with large arm circumference by race and HIV status

A. Measured brachial blood pressure						
	Black	Non-Black	*P* value[a]	PLWH	PLWOH	*P* value[a]
Number	*289*	*52*		*235*	*106*	
Prevalence	218 (75.4)	36 (69.2)	0.35	174 (74.0)	80 (75.5)	0.78
Number	*218*	*36*		*174*	*80*	
Control	47 (21.6)	8 (22.2)	0.93	40 (23.0)	15 (18.8)	0.45
B. Estimated radial blood pressure						
	Black	Non-Black	*P* value[b]	PLWH	PLWOH	*P* value[b]
Number	*289*	*52*		*235*	*106*	
Prevalence	284 (98.3)	50 (96.2)	0.29	229 (97.5)	105 (99.1)	0.44
Number	*284*	*50*		*229*	*105*	
Control	8 (2.8)	3 (6.0)	0.22	8 (3.5)	3 (2.9)	>0.9999

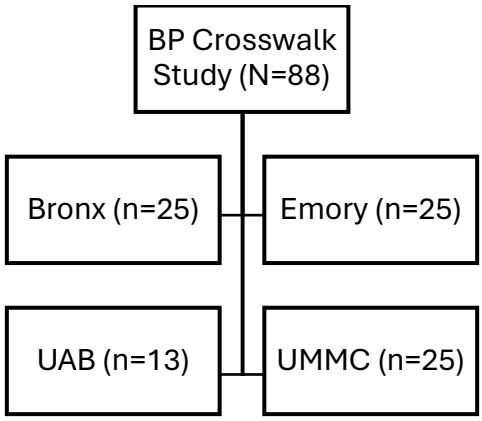
Data are presented as No. (%).

[a]Chi-square p-value.

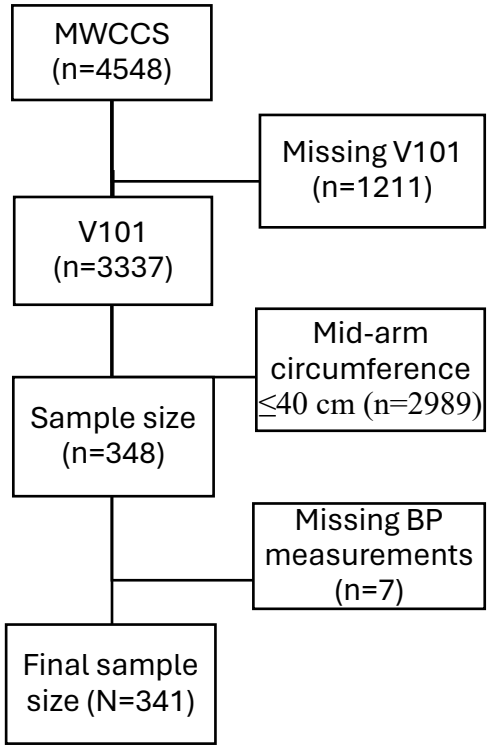
[b]Fisher's exact p-value.

Figure S1. Flowchart of exclusion criteria for participants enrolled in the Multicenter AIDS Cohort Study/Women's Interagency HIV Study-Combined Cohort Study

A. Participants in BP Crosswalk sub-study included in comparison of radial and brachial measurements



B. Participants with large arm circumference in MWCCS included in comparison of hypertension prevalence and control using radial and brachial measurements



CONCLUSION

Overall findings

In this dissertation, I sought to evaluate associations of race and ethnicity, as well as HIV status, with the hypertension treatment cascade both cross-sectionally and longitudinally. Additionally, I wanted to compare and harmonize radial and brachial blood pressure measurement among people with obesity to accurately capture hypertension prevalence and control.

Goal 1: Evaluate cross-sectional associations between race and ethnicity, as well as HIV status, and prevalence, awareness, treatment, and control of hypertension.

This cross-sectional study was conducted among women recruited into the four Southern sites of the Women's Interagency HIV Study (WIHS). The proportion of NH Black women who had prevalent hypertension (60%) was greater than the proportion of NH White and Hispanic women (43% and 25%, respectively). This relationship was seen after adjusting for sociodemographic, behavioral, and clinical risk factors in Poisson regression models. NH White women had 31% lower prevalence of hypertension and Hispanic women had 48% lower prevalence of hypertension compared to NH Black women. Although the proportion of NH Black women who were aware and treated for hypertension was greater than NH White and Hispanic women, I did not see statistically significant differences after adjusting for covariates. These findings do not align with prior studies from the National Health and Nutrition Examination Survey (NHANES).[39]

The prevalence ratios did not show higher awareness and treatment of hypertension for NH Black women compared to NH White and Hispanic women. Participation in a health-focused study, like WIHS, might explain equal awareness and treatment of hypertension among different races and ethnicities. Additionally, a substantial proportion of the WIHS cohort has access to medical care because of their HIV diagnosis, which might mitigate these differences. Participation in annual clinical visits can lead to an increase in hypertension awareness and initiation of antihypertensive medication.[10] Both the unadjusted proportion and adjusted prevalence ratio showed that NH Black women had lower control of hypertension compared to NH White and Hispanic women. The findings from this dissertation that NH Black women have higher prevalence and lower control of hypertension compared to NH White and Hispanic women are similar to results from NHANES, which is representative of the general US population.[40] Because women in WIHS had equal access to healthcare and medication treatment, psychosocial and environmental factors might explain the disparity seen in controlled hypertension by race and ethnicity. Black women have historically and currently experienced racial discrimination, which elevates biomarkers for stress and hinders management of hypertension.[41,42]

The proportion of WLWH who had prevalent hypertension (58%) was slightly greater than the proportion of WLWOH (53%). This relationship was not seen in the adjusted Poisson regression models and is similar to published work using the WIHS study.[43,44] Awareness of hypertension was comparable among both groups. WLWH were 19% more likely to use antihypertensive medication compared to WLWOH after adjusting for sociodemographic, behavioral, and clinical risk factors. Although WLWH

had higher prevalence of control of hypertension compared to WLWOH, this relationship was not significant using Poisson regression models. These findings are not consistent with meta-analyses that showed PLWH had higher prevalence of hypertension compared to the general US population living without HIV.[45] This difference can possibly be explained in that WLWOH in WIHS are matched to WLWH and share sociodemographic and behavioral factors, and the relatively small sample size. This suggests that other factors besides HIV-related criteria are associated with hypertension.[43,46]

Goal 2: Prospectively examine incidence of hypertension and hypertension awareness, treatment, and control.

This prospective study was conducted using the same cohort as seen in Goal 1. Nearly 56% of women had hypertension at baseline and among those who were normotensive at baseline, 45% developed incident hypertension during the study period. Using Cox proportional-hazards models, I did not see statistical differences by race and ethnicity for incident hypertension, awareness, or treatment. However, NH White and Hispanic women had faster time to controlled hypertension (HR=1.82 and 1.28, respectively) compared to NH Black women after adjusting for sociodemographic, behavioral, and clinical risk factors. Regardless of ethnicity, non-Black women also had faster time to controlled hypertension compared to Black women. Furthermore, the hazard ratios for race and hypertension control were not constant throughout the study period, signifying racial disparities are more prominent after years of hypertension diagnosis. My findings that NH Black women have slower time to controlled hypertension align with studies on the general US population.[47,48] However, prior studies

that compared the general US population found Black adults were more likely to be aware and treated for hypertension compared to White adults.[10,49] Because I did not find statistically significant differences by race and ethnicity and time to hypertension awareness and treatment, these findings suggest participation in a health-focused study helps eliminate gaps to access to healthcare and initiation of treatment.

Using Cox proportional-hazards model, I did not see statistical differences by HIV serostatus for incident hypertension or awareness. Although the confidence intervals were wide, WLWH had faster time to controlled hypertension (HR=1.42) compared to WLWOH. A larger sample size is required to see if this relationship persists between HIV serostatus and time to hypertension control. Among the subset of women who were normotensive at baseline and eventually developed incident hypertension during the study period, WLWH had faster time to treatment compared to WLWOH after adjusting for covariates. These findings are similar to a multicenter cohort study among Italians living with HIV, which suggests frequent visits to healthcare providers for HIV management also leads to improved hypertension management.[20] There are few US-based research studies that have examined the relationship between HIV serostatus and incident hypertension and time to hypertension treatment cascade outcomes.

Goal 3: Compare and harmonize radial and brachial blood pressure among participants with mid-arm circumference >40 cm.

I was invited by the Multicenter AIDS Cohort Study (MACS)/Women's Interagency HIV Study (WIHS)-Combined Cohort Study (MWCCS) Executive Committee to design and conduct a study to inform longitudinal analysis of BP in the

context of a change in the BP measurement protocol for participants with large upper arm circumference. This study prospectively collected data on participants enrolled in the Blood Pressure Crosswalk sub-study and applied regression analysis to participants who participated in MWCCS during 2020-2021. I found the mean within-person difference for radial and brachial systolic BP was 16.5 mmHg and the mean within-person difference for radial and brachial diastolic BP was 13.2 mmHg. Although Pearson correlation between radial and brachial systolic BP was r=0.60 and between radial and brachial diastolic BP was r=0.69, radial BP was significantly higher than brachial BP. These findings are similar to published studies examining the difference between radial and brachial BP values.[28,50] Using previously measured brachial BP, I found that 75% of participants had hypertension and 22% had their hypertension under control. I calculated separate linear regression analyses for estimated radial systolic and diastolic BP with brachial BP as the independent variable, along with covariates that are known to affect BP. Using the best fit models to estimate systolic and diastolic BP for the MWCCS sub-cohort, I found that 98% of participants had hypertension and only 3% had their hypertension under control based on the estimated radial values. The results from my dissertation suggest an artificial increase in hypertension prevalence and an artificial decrease in controlled hypertension because the American Heart Association (AHA) guidelines do not provide a threshold to diagnosis hypertension based on radial systolic and diastolic BP. The current AHA guideline for hypertension diagnosis is based on a threshold of ≥130/80 mmHg for brachial measurements despite recommending radial measurements for participants with obesity and the body research, including this study, which show that radial BP is higher than brachial BP.[51] Therefore, a new threshold to

define hypertension using radial measurements may be needed because radial BP is not representative of brachial BP.

Limitations

The results and analyses in this dissertation are not without its limitations. Due to the nature of self-report, bias can occur in participants' answers from questionnaires. Types of bias include (1) social desirability to sensitive questions like income and lifestyle choices, (2) recall bias of questions asked about behaviors and adherence to medication within the last six months, and (3) not understanding the question. Because Goal 1 and 2 utilized covariates collected at baseline entry into MWCCS, I could not evaluate lifestyle interventions that may be used before initiation of antihypertensive medications. Furthermore, information on adherence to antihypertensive medication was not collected at baseline for this cohort. I could not determine the length of time of hypertension diagnosis for participants hypertensive at baseline, which might introduce left truncation in the prospective analyses.

Our sample size for Goal 1 and 2 was limited because I excluded participants who reported race and ethnicity other than NH Black, NH White, or Hispanic due to small sample size. Specifically, few women identified as races other than Black or White, and only a small proportion of women identified as Hispanic. The sample size for the BP Crosswalk sub-study was small and included a limited number of participants assigned male at birth. Therefore, I might not have enough power to detect statistically significant differences between radial and brachial BP and sex assigned at birth. Prevalence of hypertension and control throughout this dissertation were defined at a single study visit

instead of the gold standard of BP collection at three consecutive visits.[52] For Goal 1 and 2, the results are only generalizable to WLWH and women at high risk for HIV within the Southern US. For Goal 3, the results are only generalizable to US adults with a mid-arm circumference >40 cm and are over-represented of PLWH compared to the general population.

Research implications

Participation in a health-focused study, like MWCCS, might improve hypertension management due to the increased number of clinical visits, protocols for linkage to clinical care, and better access to providers. Because women living with HIV and women without HIV in WIHS have similar demographic and behavioral risk factors, the results from this dissertation might not compare to the general US population. This could help explain the lack of statistical differences in the hypertension treatment cascade across race and ethnicity and HIV status. Since risk factors for HIV might overlap with risk factors for hypertension, our results might have less residual confounding than studies that compare PLWH to a general population.

Among PLWH, Black women are more likely to use antihypertensive medication.[53] Our study found that WLWH are also more likely to use antihypertensive medication compared to WLWOH. Further research is needed to see if the same contextual factors that are responsible for racial and ethnic disparities in the hypertension treatment cascade are also drivers of hypertension disparities among PLWH. By identifying these disparities in healthcare, clinicians and health-focused research studies can target interventions to reduce hypertension-related morbidity.

The rule of one-size-fits-all does not apply to BP cuffs, but a majority of clinical settings in the US use the regular sized adult cuff regardless of individuals' mid-arm circumference.[54] Because thigh cuffs are not properly designed for the upper arm, radial cuffs can be used for participants with obesity. The results from this dissertation show a statistically significant difference between radial and brachial BP that leads to a much higher estimated prevalence of hypertension and much lower estimated prevalence of hypertension control. Although several studies have published on this significant difference, there has not been a new threshold to define hypertension from BP collected using the radial artery. It is crucial that clinical settings utilize properly fitted BP cuffs and that a new threshold is defined using radial BP so that we can accurately diagnose hypertension and monitor treatment.

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APPENDIX

INSTITUTIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM
Office of the Institutional Review Board for Human Use

470 Administration Building
701 20th Street South
Birmingham, AL 35294-0104
205.934.3789 | Fax 205.934.1301 |
irb@uab.edu

APPROVAL LETTER

TO: Blair, Jessica

FROM: University of Alabama at Birmingham Institutional Review Board
Federalwide Assurance # FWA00005960
IORG Registration # IRB00000196 (IRB 01)
IORG Registration # IRB00000726 (IRB 02)
IORG Registration # IRB00012550 (IRB 03)

DATE: 14-Sep-2022

RE: IRB-300009549
IRB-300009549-004
Harmonizing radial and brachial blood pressures among MWCCS participants with large arm circumference

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The IRB reviewed and approved the Initial Application submitted on 14-Sep-2022 for the above referenced project. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services.

Type of Review:	Expedited
Expedited Categories:	4, 5, 7
Determination:	Approved
Approval Date:	14-Sep-2022
Approval Period:	Expedited Status Update (ESU)
Expiration Date:	13-Sep-2025

Although annual continuing review is not required for this project, the principal investigator is still responsible for (1) obtaining IRB approval for any modifications before implementing those changes except when necessary to eliminate apparent immediate hazards to the subject, and (2) submitting reportable problems to the IRB. Please see the IRB Guidebook for more information on these topics.

Linked Records:

- 000520516-0016

University Contracts, MTA, DUA, or Subcontract/Subaward Identifier(s):
DUA 000531731

Documents Included in Review:

- IRB EPORTFOLIO
- IRB PERSONNEL EFORM

Student Name: Jessica Blair
Student Project Title: Harmonizing radial and brachial blood pressures among MWCCS participants with large arm circumference

To access stamped consent/assent forms (full and expedited protocols only) and/or other approved documents:

1. Open your protocol in IRAP.
2. On the Submissions page, open the submission corresponding to this approval letter. NOTE: The Determination for the submission will be "Approved."
3. In the list of documents, select and download the desired approved documents. The stamped consent/assent form(s) will be listed with a category of Consent/Assent Document (CF, AF, Info Sheet, Phone Script, etc.)